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A process-based cost estimating tool for ship structural designs

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A Process-Based Cost Estimating Tool for Ship Structural Designs

by

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ABSTRACT

There is a significant need, and accompanying significant challenge, to concurrently consider performance, cost and production issues from the very beginning of the design process. The greatest obstacle to this approach is the lack of convenient and effective cost and performance models that can be integrated into a seamless design workbench accessible to working engineers. Traditional models and analysis methods frequently do not provide the sensitivity necessary to consider all the important variables impacting performance, cost and production. Unfortunately, achieving this sensitivity at the concept design stage almost requires a detail design level of analysis. Quick-look studies which currently are accomplished using parametric-based tools do not have this sensitivity.

The traditional design method does not adequately include production engineering or material/supplier/logistical concerns early enough to have a substantive, positive impact on the design. Taking an integrated approach, and using computer-aided cost, analysis and synthesis tools can mitigate these traditional design process failures.

This thesis develops a method to integrate an existing naval ship concept design synthesis tool (ASSET) and a commercial finite element structural analysis program (MAESTRO), with refinements to an existing structural construction cost estimating program (NSRP 0398). The integration of these separate programs provides the designer with a method of assessing the process-based cost and performance impacts associated with certain structural and hull form parameters which affect or enhance producibility. The structural parameters considered here are plate thickness, variety and number of structural shape sizes, and the use of parallel mid-body. Hull form concepts considered include shear, camber, and gaussian curvature.

The philosophy and method used to construct the integrated tool are described. The approach establishes a basis which could be used to assess the cost and performance impacts of other producibility related ideas or parameters. The approach establishes the feasibility of using Product-Oriented Design and Construction (PODAC) methods at the concept or preliminary design stage.

The major benefit of this integrated tool is that it allows some assessment at the concept design stage of the cost impact associated with details often not considered until the detailed design stage.

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Title: Professor of Naval Architecture and Marine Engineering

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DEDICATION

To my beloved wife Pamela,
without your constant and faithful prayers and support,
I would still be on page one.
I love you.

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Chapter 1 Introduction

1.1 Foreword

1.1.1 Innovation

Innovation in industry is a process that involves an enormous amount of uncertainty, human creativity, and chance. It takes place in small and large ways, and in some times and some places more than others. Professor James M. Utterback, of the Sloan School at MIT, suggests in his recent book Mastering the Dynamics of Change that the dynamics of product innovation may be described by Figure 1-1.

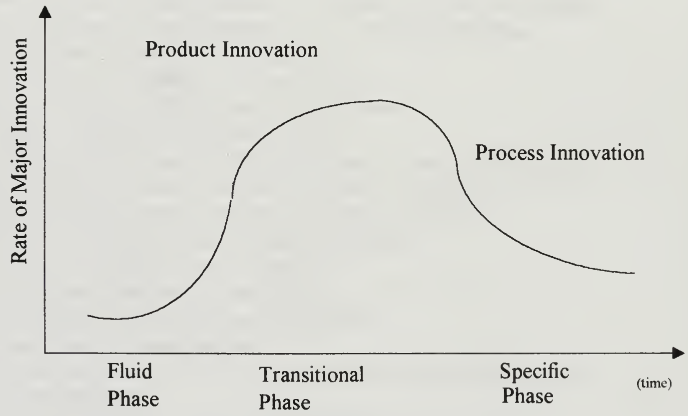

Figure 1-1 The Dynamics of Innovation
(adapted from Utterback)

The Fluid Phase is characterized by the period where the rate of product innovation in an industry or product class is highest. A good example of the fluid phase is found in the early years of the automotive industry, when a bewildering variety of machines - including electric and steam-driven cars - emerged from the workshops of dozens of manufacturers.

The Transitional Phase is characterized as a period in which the rate of major product innovation slows and the rate of major process innovation accelerates. Again, the automotive industry provides a good example, as the imaginative designs of the early auto age gave way to a set of fairly standard designs in which the form and features of the automobile achieved a measure of uniformity.

The Specific Phase is characterized as a period in which the rate of major innovation dwindles for both product and process. Industries which find themselves in the specific phase become extremely focused on cost, volume, and capacity; product and process innovation appear in small, incremental steps.

One discipline where both product and process innovation are well into the Specific Phase is naval architecture and ship design.

Utterback develops a concept of discontinuous change in a product market. He suggests that established leaders in a particular market niche face two hurdles in their conquest to prevent invading innovations from stripping away the market and reducing their product to a relic. First, the leaders need to develop an awareness of their own vulnerability - a slow and difficult process for any firm that has experienced substantial success. Recognition of an external threat is the first requirement for effective action. The second hurdle is to make the organizational adjustments that facilitate successful competition with an invading technology. The organizational problem for most established firms is that they and their technology are often stuck in the specific phase of development, while the challenger and its innovations are still in the fluid phase. The challenger brings a new and perfectible product with better performance (or performance potential), organizational flexibility, and entrepreneurial sprit; the challenger is unencumbered by human and physical assets geared to highly specific production. The established firm, on the other hand, is more bureaucratic, enjoys economies of scale (but in the wrong places), has tremendous investments in inflexible systems, and is managed by non-entrepreneurs. Under such conditions, Richard N. Foster, in his book Innovation: The Attacker's Advantage, estimates that "the contest between the slow, muscle-bound champion and the nimble challenger will go to the challenger 70 percent of the time."

Let us consider the "muscle-bound champion" to be the United State Navy, and its method of conducting ship design. And, the "invading innovation" to be a concurrent engineering approach to ship design. Instead of a profit-oriented market, let us consider the long time and great expense associated with the traditional ship design process to be the arena which the Navy is competing within. Using this analogy, we find the two hurdles suggested by Utterback to be directly applicable to the condition of Naval ship design. We all can only trust that the "invading innovation" will be adopted by the Navy.

This thesis shows how process-based cost estimating, if applied at the concept design stage, enhances the design, and addresses important issues sooner in the design cycle.

1.1.2 Naval Architecture - Organized Conservatism

Naval combatants are vessels which move over and through the water. They provide the means with which to transport payload. For displacement ships, the weight of the water displaced by the hull must balance the total weight of the ship and her payload. Hydrostatics requires that for a given displacement, the more weight allocated to the hull and structure means the less weight available for payload.

This physical fact has been the paradigm which has dominated naval architecture, if not for centuries, certainly since the advent of iron ships. Traditional wisdom has commanded that all parts of the ship which are not the cargo, be as light as economically feasible while maintaining sufficient structural integrity. Since it is the payload that is usually of primary importance, ship designers, and especially naval architects, have been conditioned to design the ship's hull to be as efficient as the rule-based or classification society-based codes and rules-of-thumb allow.

There is nothing wrong with designing a strong, light ship to be sure. However, if care is not taken, the ship will be exceedingly difficult to fabricate and maintain. Not only will the design and construction costs be higher than required, but the life cycle costs will be higher.

Naval architecture is an applied science which is extremely conservative. It is not easy to challenge yesterday's design paradigms and standards since, generally speaking, the ships built thereby continue to be a success. Yet, despite the fact that these same ships are the most complex, and are the largest mobile structure constructed by man, they are considered to be commodities by most of the world market.[1]

Since ships are so large, full scale prototypes and full scale testing are not generally practicable. Therefore, the design must be "right" to begin with. This is especially true for combatants which, ton-for-ton, are considerably more expensive to build than commercial ships. Combatant ship designers have been conditioned to optimize performance and minimize design risk.

So the risk-adverse ship designer desires to know what has worked in the past. To realize these successes, naval architects have conducted regression analyses of ships based on dozens of "successful" ship characteristics (length, speed, draft for example) and non-dimensional metrics (prismatic and block coefficients, for example). The results of these analyses are "design lanes" or design boundaries for the ship characteristics and non-dimensional metrics. The design lanes, if not exceeded, tend to "guarantee" the new design to be successful. While the use of design lanes leads to successful ships, it tends to stifle innovation and forward thinking.

Since a design is not "new" without something being new or different than past designs, the risk-adverse ship designer desires to include up-dated technologies or concepts which have been "proven" to work in other, similar applications or well documented model tests. The cautious adoption of new technology, new criteria and new design concepts allows ship designs to proceed successfully, and at a low level of risk. While this approach has had some successes, it has hampered innovation.

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[1] While this is not so militarily; it is certainly true in the commercial arena. (Mr. Paul Slater, CEO First International Group of Companies, @ NSRP Ship Production Symposium, San Diego, CA 1996)

1. Concept Design

The first step in concept design translates the mission requirements into Naval Architecture and engineering characteristics. Feasibility studies determine such fundamental elements of the proposed ship as length, beam, depth, draft, fullness, power or alternate characteristics, all of which meet the required speed, range, cargo cubic, and deadweight. The concept design is used for obtaining approximate construction costs, which often determine whether or not to initiate the next level of development, Preliminary design. (Kiss)

2. Preliminary Design

Preliminary design further refines the major ship characteristics affecting cost and performance. Certain controlling factors, such as length, beam, horsepower, payload fraction (naval) or deadweight (commercial) would not be expected to change significantly in this phase.

It is in preliminary design, however, where basic decisions are made such as structural components, scantlings and the principal structural materials such as high strength steel, high yield steel, ordinary steel or combination of these. Its completion provides a precise definition of a vessel that will meet the mission requirements. This provides the basis for development of contract specifications. (Kiss)

3. Contract Design

The Contract design stage yields a set of plans and specifications which form an integral part of the shipbuilding contract document, further refining the preliminary design. (Kiss) The contract design becomes the legal and binding document used, especially during arbitration, to resolve and settle the cost of the ship.

4. Detailed Design

Detailed design is the final stage, and is the development of detailed building plans. These plans are the fabrication, installation, and construction instructions to the professionals, machines, equipment and computers which will ultimately build the components of the ship. They include production details tailored to meet shipyard unique requirements, restrictions and limitations. As part of the detailed design, transition design is developed to translate system-based plans to process-based instructions.

It is at this stage where there must exist a smooth interface between the design engineers, the production engineers and tradesmen/artisans. This interface must facilitate an efficient exchange of detailed information. This interface is the cornerstone of a successful transition design. In theory, this efficient exchange of information ensures that the final product meets the design requirements, which represent the needs, desires, and specifications of the customer. Additionally, the shipbuilder must produce the ship on cost and schedule to ensure an acceptable cash flow and profit (which are not one in the same) for the shareholders.

Yet, there is the ever present need for innovation: better designs and more efficient fabrication techniques. Fuel costs force better hydrodynamic efficiency, harbor environmental concerns force lower slow-speed propeller wash, navigational constraints force better maneuvering and control systems, sophisticated enemy sensors warrant more stealth of ownship sensors and the hull itself. Market drivers force accuracy control and distortion mitigation techniques.

There is a significant need, and accompanying significant challenge, to concurrently consider performance, cost and production issues from the very beginning of the design process. The greatest obstacle to this approach is the lack of convenient and effective cost and performance models which can be integrated into a seamless design workbench accessible to working engineers. Traditional models and analysis methods frequently do not provide the sensitivity necessary to consider all the important variables impacting performance, cost and production. Unfortunately, achieving this sensitivity at the concept design stage almost requires a detail design level of analysis. Quick-look studies which currently are accomplished using parametric-based tools do not have this sensitivity.

This thesis furthers the argument for a new philosophy to be used for naval ship structural designs. The new philosophy is to apply concurrent engineering and Product-Oriented Design and Construction (PODAC) methods at a relatively detailed level early in the design process.

The thesis provides a tool which integrates an existing design synthesis tool (ASSET), a commercial finite element structural analysis computer program (MAESTRO), an existing structural construction cost estimating computer program (NSRP 0405), and concludes with a brief assessment of life cycle cost and performance. The result is a tool which allows a quantitative analysis of the cost of applying ship producibility features such as flat sides, parallel mid-body and a reduced variety of interim products. The tool enhances an assessment of the performance impacts of the inclusion of producibility features into the design. Further, the tool reveals the cost impact of post-weld plate/panel distortion remediation on a design, a problem which has long been acknowledged, yet never incorporated into even the preliminary design.

The philosophy relies on the application of concurrent engineering, and, product oriented design and construction methodology at the earliest opportunity during the design process. This ensures pertinent factors traditionally neglected until late in the design process, which ultimately delay the delivery and increase the delivered cost of the vessel, are incorporated during early decision-making steps. Early incorporation of these items allows assessment of their impact on the vessel's design and performance.

1.2 Background

1.2.1 Traditional Basic Design Process

The Basic Design Process is traditionally composed of four (4) relatively distinct stages. These stages are Concept, Preliminary, Contract and Detail Design.

A closer look at each of these phases of design exposes some inefficiencies which often lead to a sub-optimized ship.

1.2.2 Inefficiencies of Traditional Design Process

1. Late Design Considerations

As the preceding discussion indicates, there are many characteristics of the ship which are established very early in the design process. Among these are:

- length;
- beam;
- depth;
- prismatic coefficient;
- maximum transverse section coefficient;
- hull material(s)
- and offsets.

These characteristics are traditionally developed using historical design parametrics as in the ASSET surface ship design synthesis tool.

Once the hull offsets are established, the displacement is defined and anything tending to increase the weight of the ship results in consumption of the design margin. Conflicts between competing demands for space and weight are handled using design budgets.

The traditional design method does not adequately include production engineering or material/supplier/logistical concerns early enough to have a substantive, positive impact on the design. Taking an integrated approach, and using computer-aided cost, analysis and synthesis tools can mitigate these traditional design process failures.

2. Weight-Based, Macro Cost Estimates

Cost estimates are often grouped into two categories. The macro, weight-based, top-down, historical approach is the first category, and the micro, bottom-up, process-based engineering analysis approach is the second category. The macro approach has been the traditional approach largely due to the fact that it is easier to apply, obtains "results" quicker and does not require much design detail. In this approach, historical data are used to develop cost estimating factors. These factors are usually based upon weight, that is, fabrication man-hours per net steel ton. The factors reflect past practices and experience. This approach provides a gross estimate before the design is completed.

From a producibility perspective, there are four major deficiencies to macro estimates. First, they are based upon historical cost returns. Shipyards are traditionally poor sources of cost information. The data frequently are skewed reflecting pressures on the first-line managers and other factors (Kraine).

Second, by being based on historical data, macro estimates tend to continue inferior past practices and inefficient decision-making choices. Such design choices, once made, since they are not often analyzed to discover the cause of the inefficiencies, perpetuate un-checked into future designs (Kraine).

Third, by being based upon weight, any change which increases weight will automatically increase the cost estimate regardless of the actual effect on cost. Cost reductions which result from weight increases tend to be discounted or ignored, since they represent an opportunity for the shipyard to recoup some revenue lost in other places of the design. This aspect of macro estimates leads to an overemphasis upon weight as a means of cost control. An example of this is the traditional effort to reduce deck height. Since a lower deck height requires less steel and other weight, the cost is predicted to be lower. The choice to lower the deck height typically does not effectively account for the increased cost for outfitting due to the cramped conditions (Kraine).

Finally, macro estimates do not permit the cost comparison of the features or details of a design which is necessary for selecting the lowest cost design approach at each step. (Kraine) The macro approach does not facilitate analysis of how inclusion of producibility measures affects other performance measures other than cost. For example, the weight based approach cannot reward design concepts which achieve the same performance through the use of flat panels and knuckles above the waterline.

The macro approach does not reward the use of a standardized, and perhaps smaller, parts list which would be less costly to service and maintain. The standardized parts list, especially if it has fewer different orderable parts would tend to be more adaptable to the less expensive Just-In-Time delivery system. Reducing the number of individual types of items which the shipyard must process (receive, prepare, store, transport, etc.) would likely incur a cost savings. For example, if the same performance could be achieved through a design of 100 unique parts or 20 each of five different parts, the latter would require less non-value added labor, and would therefore lead to a cost reduction. Additionally, the life cycle implications of having to maintain a supply and logistic system to support the 100 unique parts would be more expensive than the 20 each of five different parts. Clearly, macro estimates are not supportive of improving producibility in ship design.

The following selected portion of a discussion for an article entitled "Producibility in Ship Design" by Kraine is a clear example of the emotional inertia which must be overcome in order to obtain the more rational approach of process based cost estimating (Kraine).

"Cost estimating- The general comments within the section titled "Estimating Costs" caused some concerns which we will share with you... The authors conclude that macro estimates "...are not supportive of improving producibility in ship design." Further, NAVSEA cost estimating is macro based, and burdened by the above four shortcomings, it is inherently dampening to innovative ship producibility concepts.

We disagree, and we believe the following to be true.

1. All cost modeling is historically based. And, like it or not, the nation's best sources of shipbuilding cost information are the shipyards.

2. Understanding the past better equips the cost estimator's ability to predict the future.

3. Weight is universally accepted as a cost driver, but weight increases will cause cost increases only when all other things are held constant. Blind use of weight estimates or of cost-estimating relationships will always result in incorrect cost estimates.

4. Models do not produce incorrect cost estimates, estimators do! Creative use of macro based models is quite possible and can permit realistic, comparative cost estimates of new innovative concepts.

5. Lack of producibility innovations in ship designs is not a result of shortcomings in cost estimating techniques.

Our conclusion: Nothing is inherently wrong with macro based cost estimating or, for that matter, with the NAVSEA methods.

More, the issues are understanding the "historical" cost data sources and properly using the data when estimating the cost of future ship designs" (emphasis in the original) (Robert R. Jones, David Taylor Research Center, and Vern Stotz, Naval Sea Systems Command).

These gentlemen are leaders in their field, yet they are missing the point concerning the necessity to include producibility concepts at the concept design level. I shall quickly address their points, one by one.

1. Yes, all cost modeling is, and shall always be historically based, yet just because the shipyards have traditionally only been able to supply incomplete and sporadic cost information does not require that the Navy, their largest customer today and in the foreseeable future, accept these past practices.

2. Yes, understanding the past does lead to a better prediction of the future. That is precisely why it is important to do detail analysis of good and useful cost information - in order to better predict the future.

3. Yes, weight is a, not the, cost driver. A process based cost estimating system would allow analysis of not only the impact of weight, but of other aspects of the design on the cost of fabrication and life cycle maintenance and operations.

4. Yes, macro based models can permit comparative cost estimates, yet they will continue to be insensitive to process based cost factors such as distortion mitigation.

1.2.3 Enhancements to Basic Design Process

1.2.3.1 Micro Cost Estimating Approach

The micro, bottoms-up, engineering analysis cost estimating approach breaks the project into smaller and smaller interim products until the most basic product (e.g. flat bar) is described. All costs for receiving, processing, tracking, coating, and fabricating this product, along with its associated interim products, into the next, more mature interim product are estimated. The estimated cost of each layer interim product is summed with all preceding layers, thus obtaining a cost which reflects an engineering analysis of the building process. This approach uses cost factors, but they are based on work studies and actual costs of products. The process distinguishes between such subtleties as the difference between the man-hours per foot of automatic, downhand butt welding, and the man-hours per foot of automatic, downhand fillet welding.

1.2.3.2 Non-Traditional Cost Estimating

The traditional cost estimating methods largely focus on two ways to reduce cost. These are through a reduction in direct material costs and direct labor costs. These reductions are vigorously pursued through many avenues including substituting cheaper material or fabrication techniques, reducing wasteful labor practices, automating labor practices. Yet focusing only on these two areas ignores the equally important areas (at least from the perspective of the shipyards) of overhead, financing rates and terms and design changes which are the result of incomplete concurrent engineering.

The impact of finance rates and terms on structural cost estimating is beyond the scope of this thesis, and overhead and design changes are not explicitly excluded. Non-value added, but necessary operations such as storing, lifting, transporting and marking are overhead items which will be addressed. The overall thrust of the thesis, which is to integrate ship synthesis with structural analysis and cost estimating is a direct attempt to avoid design and engineering changes which might develop as a result of insufficient engineering early in the design process.

1.2.3.3 Concurrent Engineering Approach

It has been said that Design involves seeking the right problem to solve, while Engineering involves solving the "right problem". Concurrent engineering seeks to perform both design and engineering simultaneously. In order to achieve concurrent engineering, the product design process must be "re-tooled" from the traditional "over the fence" approach to a new approach. All functions, whether they be design, engineering, or support functions must work as a team in parallel, plan early, validate often and maintain oversight of product life cycle decisions within their control (T. Lamb, quoting Dr. Ralph Wood, Concurrent Engineering Application and Implementation for U.S. Shipbuilding Workshop).

The generally accepted definition of Concurrent Engineering was prepared for the Institute of Defense Analysis (IDA) in 1986, and is:

> Concurrent Engineering is a systematic approach to the integrated. concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule and user requirements.

Concurrent engineering requires teamwork. Teamwork occurs when individuals in a group or organization behave in a cooperative manner with all other individuals for the benefit of the group or organizations as a whole. Teams are a group of individuals established to accomplish a specific purpose. While it has been suggested that teamwork is possible without forming teams (Bennet, 1995), this is wishful thinking.

Concurrent engineering is not new. It has been used by many highly successful companies in many industries to vastly improve performance. Concurrent engineering is often implemented by companies because they need change to survive changing times and vendor/customer demands. (Concurrent Engineering Application and Implementation for U.S. Shipbuilding Workshop).

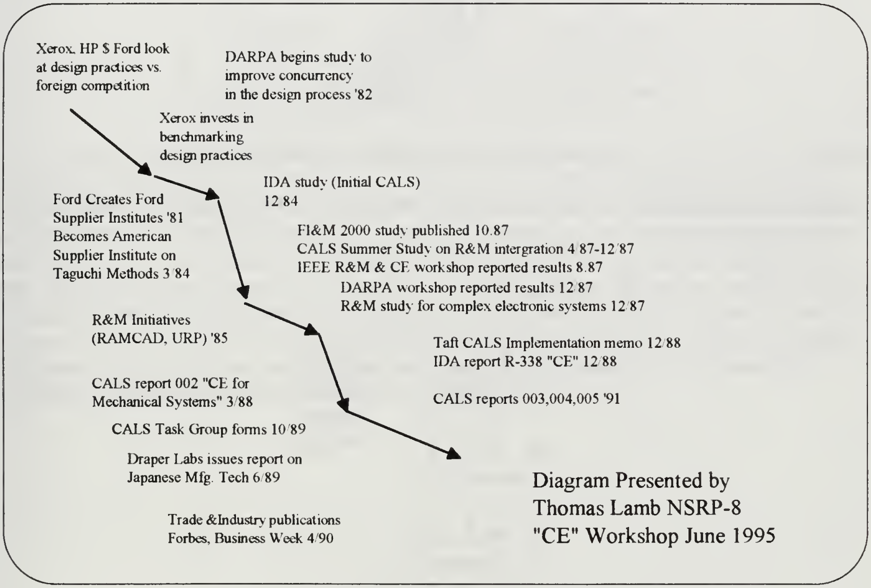

Figure 1-2 Historical Perspective of Concurrent Engineering

Some things concurrent engineering is not. It is not sequential. Figure 1-3 presents in block diagram form a sequential product design process.

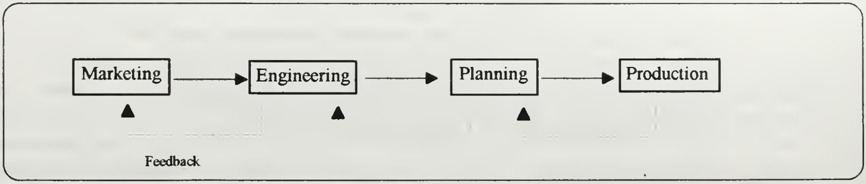

Figure 1-3 Sequential Product Design Process

Concurrent engineering is not overlapping. Figure 1-4 presents in block diagram form an overlapping product design process.

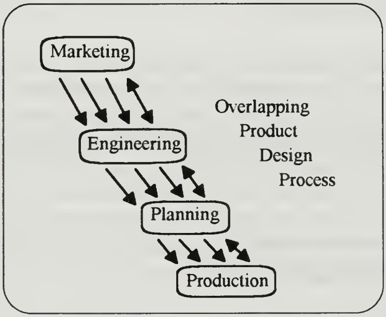

Figure 1-4 Overlapping Product Design Process

Concurrent engineering is not parallel. Figure 1-5 presents in block diagram form a parallel product design process.

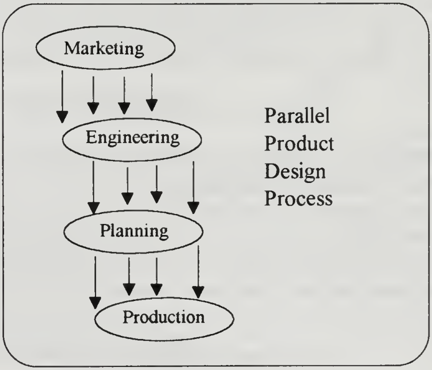

Figure 1-5 Parallel Product Design Process

It is a network of design processes.

It is suggested that concurrent engineering is a potential way to provide the necessary competitive advantage to gain a favorable market position or to achieve hitherto un-obtainable design goals. The goal of concurrent engineering is to produce interim products, whether they be design sheets, parts or assemblies, that meet (not exceed) the given function and quality requirements in the shortest time and lowest overall cost (NSRP-8 Industrial Engineering Panel on Concurrent Engineering Primer).

The concurrent engineering benefits, as reported in the NSRP-8 Primer are listed in Table 1-1.

Table 1-1 Concurrent Engineering Benefits

Category	**Percentage Benefit**	**Type of Benefit**
Development Time	30-70%	Reduction
Engineering Changes	65-90%	Reduction
Time to Market	20-90%	Reduction
Overall Quality	200-600%	Improvement
Productivity	20-110%	Improvement
Dollar Sales	5-50%	Improvement
Return on Assets	20-120%	Improvement

For the concurrent engineering approach to be successful, it must not be called or referred to as "concurrent engineering". This term, while accurate, is cliché and pre-disposes potential team members to be biased against participation (Huthwaite 1995). The effort must be completely and fully endorsed starting from the top. The product must not be designed first on a concurrent engineering team, rather, design the "team process" which will be the core of the design effort first. This ensures the social dynamics, conflict resolution techniques and priority setting strategies are fully in place prior to beginning the engineering. Further, not only should the product success be measured but the process success or effectiveness must be measured. To measure the design and process success, certain things must be designated for measurement and at a prescribed periodicity. Such measurements are referred to as Metrics.

With concurrent engineering, a Metric is a quantitative measurement of a system, component or process to determine the degree to which it possesses a given attribute. Using metrics is important for the concurrent engineering team and those personnel or entities outside the team which are providing information to or using output from the team. The Metrics should be:

- simple;
- easily obtained and understandable;
- objective so that stakeholders with different backgrounds and experiences will likely assign the same value to the Metric;
- valid, measuring that which is intended to be measured and not a secondary issue;
- robust, insensitive to small changes in the product or process;
- must provide a basis for predictive process modeling.

There are two dominant skills necessary for concurrent engineering to be effectively implemented: design skills and team dynamics skills, and they must be worked in tandem. Concurrent engineering is customer, process and team focused. While "customer" obviously means the purchaser and user of a product, it also means the company's internal users of the output from the different processes involved in producing the product, whether the product be a design specification sheet or a physical part.

There are numerous road blocks to the successful adoption of concurrent engineering philosophy and to its successful implementation. There are three distinct phases where these road blocks are likely to occur. The first phase is the Initial Phase, where the concept is being explored and things are "getting started". The second phase is the Preparing/Planning phase, where a commitment has been made, yet the path to success is not clearly understood by all. The third phase is the Execution Phase, where the pursuit of success is under way.

During the Initial Phase, some common road blocks are:

- no managerial champion to promote the cause;
- no benefit/cost analysis performed to validate the plan;
- lack of sufficient investment in initial phase;
- poor managerial vision, poor communication of good managerial vision down the chain of command,
- organization which attempts a large scale concurrent engineering endeavor with little or no experience.

During the Preparing/Planning phase, some common road blocks are: inconsistent senior management priorities which conflict with the goals of concurrent engineering, the attainment of only partial functional cooperation, cultural paralysis preventing implementation of aspects of concurrent engineering, inadequate group decision making techniques, poor interpersonal communication practices, poorly conveyed strategic plan, inadequate integration of the necessary tools or models for successful integration of team members and their functions.

During the Execution phase, some common road blocks are: middle management hijack where managers are removed from the concurrent engineering endeavor during a critical state, no direct supplier interface during the design, technical expertise guarded too closely, no metrics developed to measure the design process, too rapid expansion from the pilot to new projects before the lessons learned from the pilot are understood and the strategies to prevent recurrence are in place, insufficient or improper metrics, incomplete cooperation from team members, insufficient empowerment to provide designated personnel the tools and authority necessary to be successful.

Concurrent Engineering Summary.

The First Truth is: Design is the primary driver of quality, time and cost. Design "drives" 70% or more of the typical cost and product success in the commercial market place. (Huthwaite, 1995) (Munroe, 1996) Industry typically spends too much, too late for the product or component to be effective in the market place.

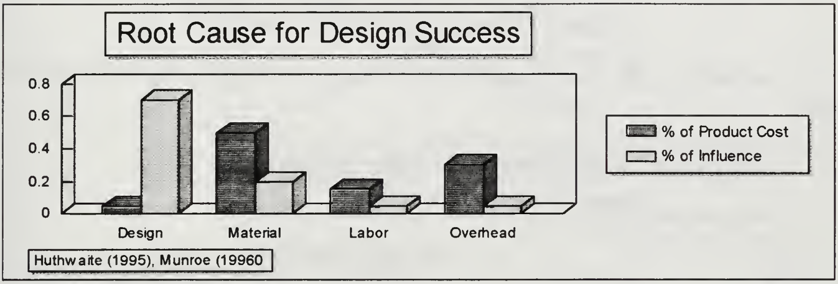

Figure 1-6 Root Causes for Design Success

The Second Truth is: There always exists the need to leverage the power of design into the product earlier, broader and deeper. This truth seeks to ensure design process improvements are more than superficial, and that they reduce not only the traditional labor and material cost, but the service, implementation, administrative and other "Burden" or overhead costs. The goal is to focus the design effort up-front.

Huthwaite and Munroe independently suggested the following relationship between the commitment to a particular course of action and the cost associated with that course of action which is typical in today's industrial product development.

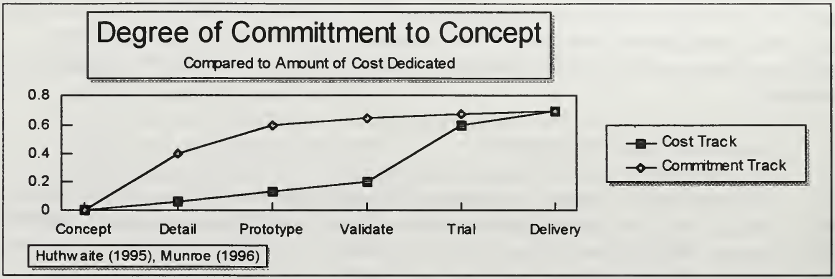

Figure 1-7 Degree of Commitment to Concept

The following adapts this relationship to ship designs. Notice the new labels along the x-axis.

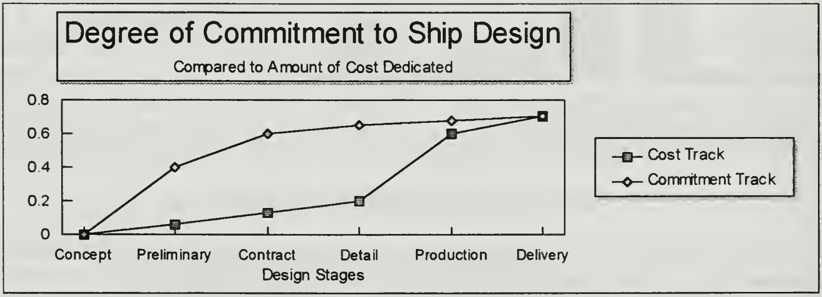

Figure 1-8 Degree of Commitment to Ship Design

The Third Truth is: The multi-functional team is the key to the effective, total design equation. The multi-functional team must include process owners who will be involved from the very beginning of the design. These process owners are those individuals which will ensure the design matches the various processes through which the raw stock must proceed prior to ultimately becoming the final product; these include material receipt and preparation, as well as the actual fabrication steps.

The Fourth Truth is: Great Innovation is only as good as great implementation. The success of concurrent engineering is predicated on implementation of the entire design process. The early, pro-active involvement in the design process of all those who must eventually make the total product a success requires that people replace the traditional "review" mentality and adopt an "ownership" mentality.

The Fifth Truth is: <u>While the cost of implementing changes increases tenfold with the passing of each stage of fabrication, the design flexibility decreases over the design cycle inversely with cost.</u> Therefore, the more "conflicts" which can be resolved up-front the better for the design and for cost.

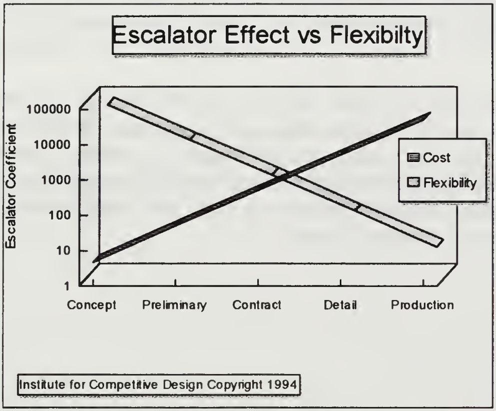

Figure 1-9 Escalator Effect vs. Flexibility

1.2.3.5 Process-Based Measures of Performance

The use of process-based measures of performance is a superior method of measuring system or component performance. The process-based cost estimate, while being more difficult to establish, once established is no more difficult to maintain than a weight based estimate. The process based cost estimate attempts to model the actual fabrication scheme, describing at varying levels of detail the actual cost associated with certain processes or procedures. In order to achieve a sufficient level of detail, a good understanding of the process and a relatively tailored model of the specific process must be developed in order to attempt to reflect the actual man-hours and material consumed. This is both the liability and the power of the process-based model.

Should actual material and labor costs be made available to perform analyses of both weight-based and process-based cost estimates, it should be self evident that since the process-based scheme is more closely aligned with the true fabrication practices that it will prove to be the superior estimating method.[2] The simplicity of this truth has thus far escaped application.

The use of increases in material weight, that is, plate thickness, structural shape sizes, etc., as a trade off when a decrease in man-hours can be achieved is desirable, yet, as previously discussed, invariably results in a cost penalty due to the weight based measure for cost. "The increased material cost is more than compensated for by the reduced labor cost while the change in total light ship weight may not be significant. This has been validated by calculation and actual construction results. However, a small increase in light ship weight might well be acceptable to realize a significant reduction in construction man hours" (Kraine, et al.).

1.3 Summary

Innovation is required in structural design and cost estimation. The use of concurrent engineering, and in particular a process-based design and cost scheme, in concept design is the solution to reducing errors during production caused by design errors, to reduce the overall design time and to shorten the build cycle for naval ships. This thesis develops a process-based cost estimating tool for ship structural design.

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[2] This statement neglects re-work due to errors not caught at the completion of fabrication of each interim product. The compounding of errors due to mis-identified or ignored mistakes will be inevitable in any cost model. This makes it ever the more important for the craftsman to be empowered to affect change and identify errors/mistakes quickly.

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Chapter 2. Ship Structural Design

The rule-based structural design methods in ASSET do not always provide structures of adequate integrity. More sophisticated analyses are required. Rationally-based structural analysis, such as MAESTRO, is a superior method. To use MAESTRO requires describing the ship in more detail than ASSET. However this is a manageable endeavor for concept design. Since to use rationally-based structural analysis, some level of detail is required, other analyses, such as cost and performance measurement are also enhanced. This allows a ship design to be conducted more simultaneously than the traditional design spiral.

2.1 Rationally-Based Structural Design

In its full capacity, the rationally-based design procedure used by MAESTRO[3] can be described as follows:

> "1. The external loads are predicted as accurately as possible, using statistical methods where appropriate.
> 2. The load effects and limit values of load effects are calculated accurately throughout the structure for all load cases.
> 3. The minimum required margins between the load effects and their limit values are all selected on the basis of a required degree of safety.
> 4. The resulting strength requirements are expressed in the form of mathematical constraints on the design variables (in most cases nonlinear constraints).
> 5. The designer is left free to specify the measure of merit of the structure, that is, the criteria that is to be used in achieving the best structure, and the influence of each design variable on the measure of merit. Also the designer is able to specify any number of other constraints on the design, of any form whatsoever, in addition to the strength-related constraints.
> 6. An optimization method automatically and efficiently solves for the values of the design variables which give the maximum value of the measure of merit while also satisfying all of the constraints (Hughes)."

Figure 2-1[4] illustrates the overall rationally-based design process, consisting of these six tasks. All of the tasks are large, and require the designer to have at least a basic knowledge of the underlying theory and methods of structural analysis. For a complete description of MAESTRO, the reader is referred to the text.

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3 Method for Analysis, Evaluation and STRuctural Optimization, Owen F. Hughes

4 Figure 2-1 is a representation of Figure 1-1 found in SHIP STRUCTURAL DESIGN.

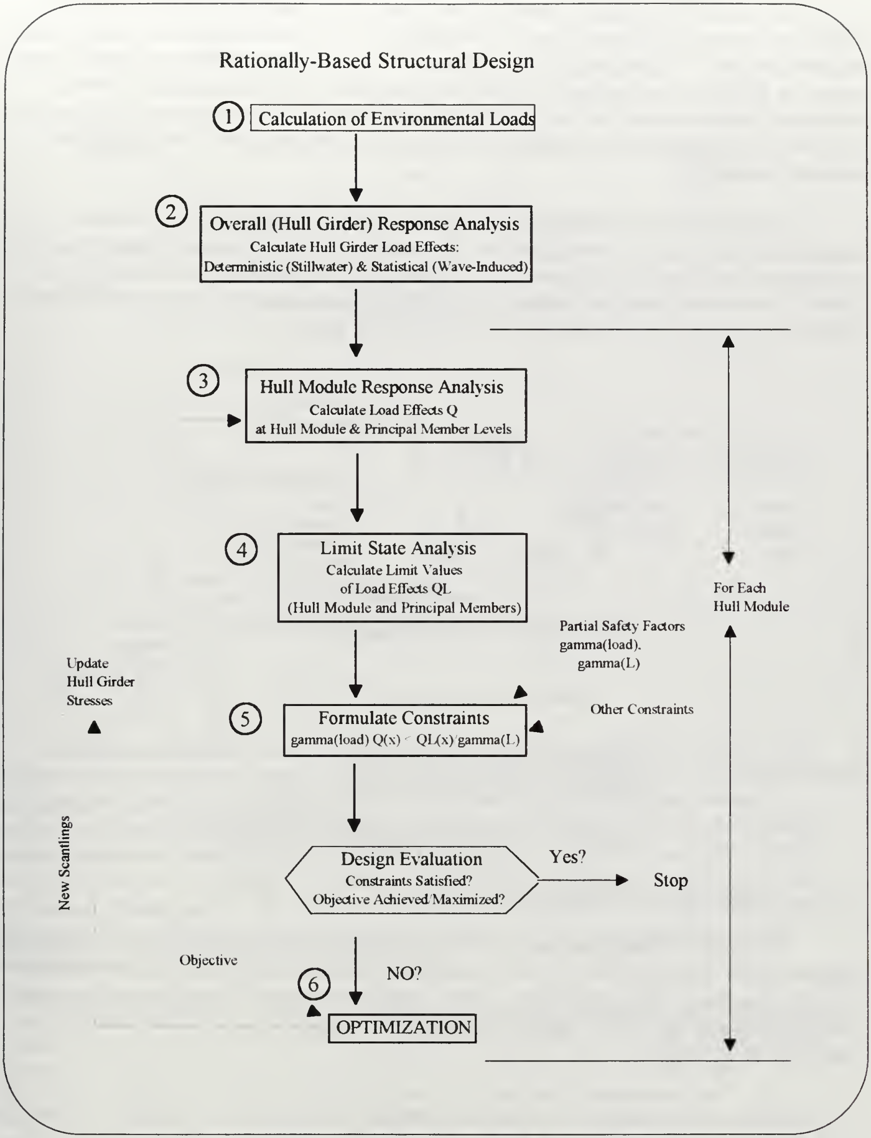

Figure 2-1 Rationally-Based Structural Design

The MAESTRO computer program has a robust optimization feature which allows the designer to constrain, for example, girder web height to be no smaller than a frame web height and no larger than 2.5 times larger than a stiffener web height. The program is not limited to the number or flexibility of such physical dimension optimization. Yet, the optimization does not account for distortion which fabricating large stiffened panels, or the cost savings which could be enjoyed by the shipbuilder (and passed on to the customer) through quantity buys of selected structural members.

Therefore, while a rationally-based structural design is far superior to a rule-based structural design, it is not a stand-alone tool. The analytical power of rationally-based design must be integrated with other tools. Figure 2-2 presents in block diagram form the basic steps, and feedback, experienced using the <u>traditional structural design philosophy</u>. Whether the structural design is rule-based or rationally-based, the process is the same.

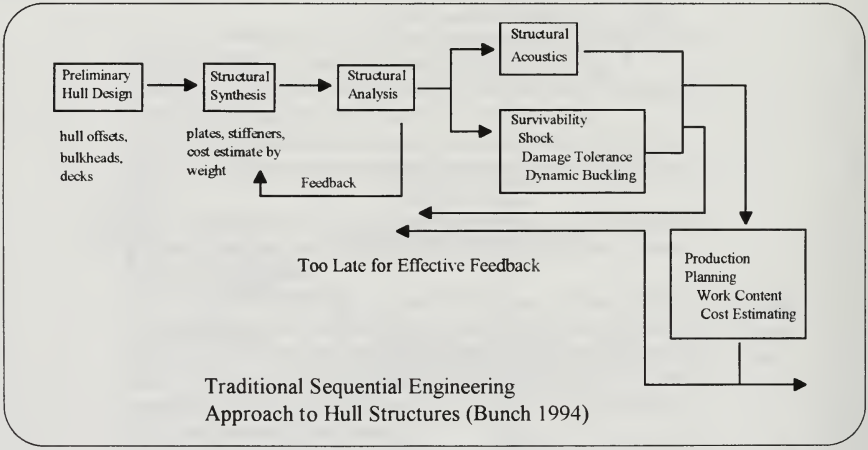

Figure 2-2 Traditional Sequential Engineering

2.2 Application of Concurrent Engineering

The traditional design process has been and remains to be highly successful. The difficulty with the "spiral" process is that it is the connection of individual efforts, and therefore promotes the "over-the-fence" design philosophy. If short design cycles and short ship fabrication periods are not of concern, the "spiral" approach is satisfactory. Figure 2-3 presents one version of the traditional design spiral.[5]

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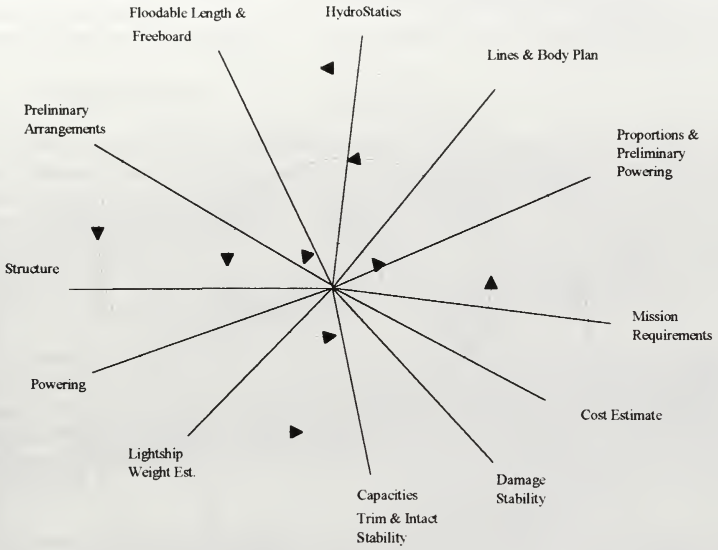
[5] There are any number of arguments concerning what are the total number of stations, their most appropriate titles, and the best sequence; propose here, along with others before (Bunch, Chirillo, Storch to name a few), to move beyond the "spiral" concept, resolution of these issues here is mute.



Traditional Design Spiral
(adapted from SHIP DESIGN and CONSTRUCTION)

Figure 2-3 Traditional Design Spiral

There is a significant need, and accompanying significant challenge, to concurrently consider performance, cost and production issues from the very beginning of the design process. The greatest obstacle to this approach is the lack of convenient and effective cost and performance models which can be integrated into a seamless design workbench accessible to working engineers. Traditional models and analysis methods frequently do not provide the sensitivity necessary to consider all the important variables impacting performance, cost and production. Unfortunately, achieving this sensitivity at the concept design stage almost requires a detail design level of analysis. Quick-look studies which currently are accomplished using parametric-based tools do not have this sensitivity.

As was developed in Chapter 1, concurrent engineering attempts to near-simultaneously bring to bear the appropriate talents and tools necessary to consider not only first or leading factors which affect the overall design, but the second, third or even the fourth level of factors. The more robust the preliminary design process, the better the design process can near-simultaneously consider competing interests, and reach an "optimal preliminary" solution. The better the "optimal preliminary" solution, the better the ultimate design.

A two dimensional representation of such a "network" is difficult; Figure 2-4 attempts to represent such a network.

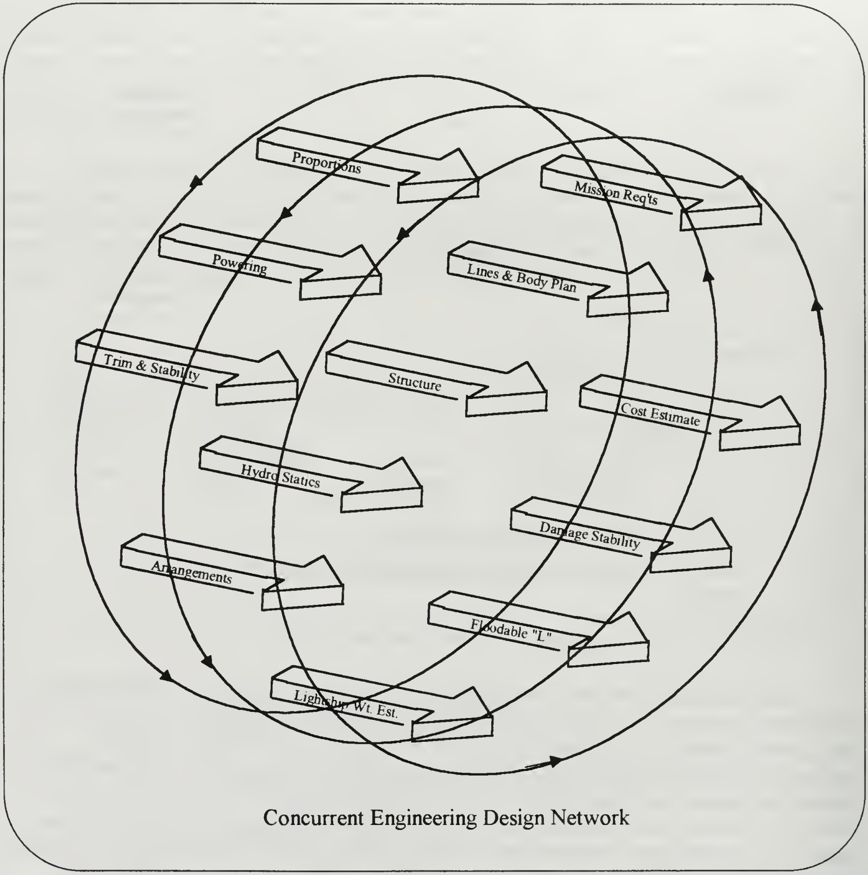


Figure 2-4 Concurrent Engineering Design Network

To this end, the rationally-based structural design which formerly was a station along the design spiral, is an integral tool within the design network.

What is needed is a robust method of near-simultaneous integration of all design elements. Such a process is the process-based design philosophy, maybe referred to as Process Oriented Design and Construction (PODAC) (Bunch). PODAC is a multi-tiered approach. The topmost tier integrates all of the former stations along the design spiral, yet within each former station, PODAC may be applied.

The issue here is the application of PODAC to structural design and cost estimate. The three elements of structural design and cost estimate which warrant integration in order to achieve the goals of concurrent engineering are: design synthesis, analysis and cost estimation.

2.3 Design Synthesis

Synthesis may be defined as the combination of parts or components to form a whole. Design Synthesis, therefore, is the combination of the all former stations of the design spiral to achieve a whole or complete design simultaneously. The United States Navy's Advanced Ship Synthesis Evaluation Tool (ASSET) is a rule-based, parametric-based and regression-based method of achieving synthesis for naval combatants. Some of the rules of thumb used within the individual ASSET modules are contained within "design lanes" which are the product of years of experience and regression analysis of historically successful ships.

A preliminary-design-level synthesized and balanced ship may be achieved using ASSET, yet there are compromises involved which are not based on rudimentary algorithms, and, particularly for structural design and analysis, they are no longer acceptable. ASSET uses weight-based cost estimating algorithms. Further, as outlined in Chapter 6, the structural sizing and analysis methods used by ASSET can not be used to model producibility-related structural design issues.

However, ASSET is a convenient and cost effective method to realize, and in some cases visualize, the impacts of changes to ship characteristics on the overall design. ASSET will be used to develop ship characteristics, and perform analysis of the impact the structural design has on the overall ship, its performance and cost.

Figure 2-5 presents, in block diagram form, the overall steps necessary to balance a ship, and the general design priority and sequence used by ASSET. At the concept design stage, a balanced ship is one where all the major characteristics of the ship are consistent. The volume supports the weight with a suitable stability, the installed propulsion plant and drive train adequately propel the hull to achieve the desired speed requirements, the installed electrical system provides adequate power to the installed equipment under the prescribed operational conditions, and so on. A balanced ASSET ship is not necessarily feasible. A feasibility study must be performed to validate the balance, but a complete concurrent engineering effort will conduct the feasibility study during the formation of the concept design.

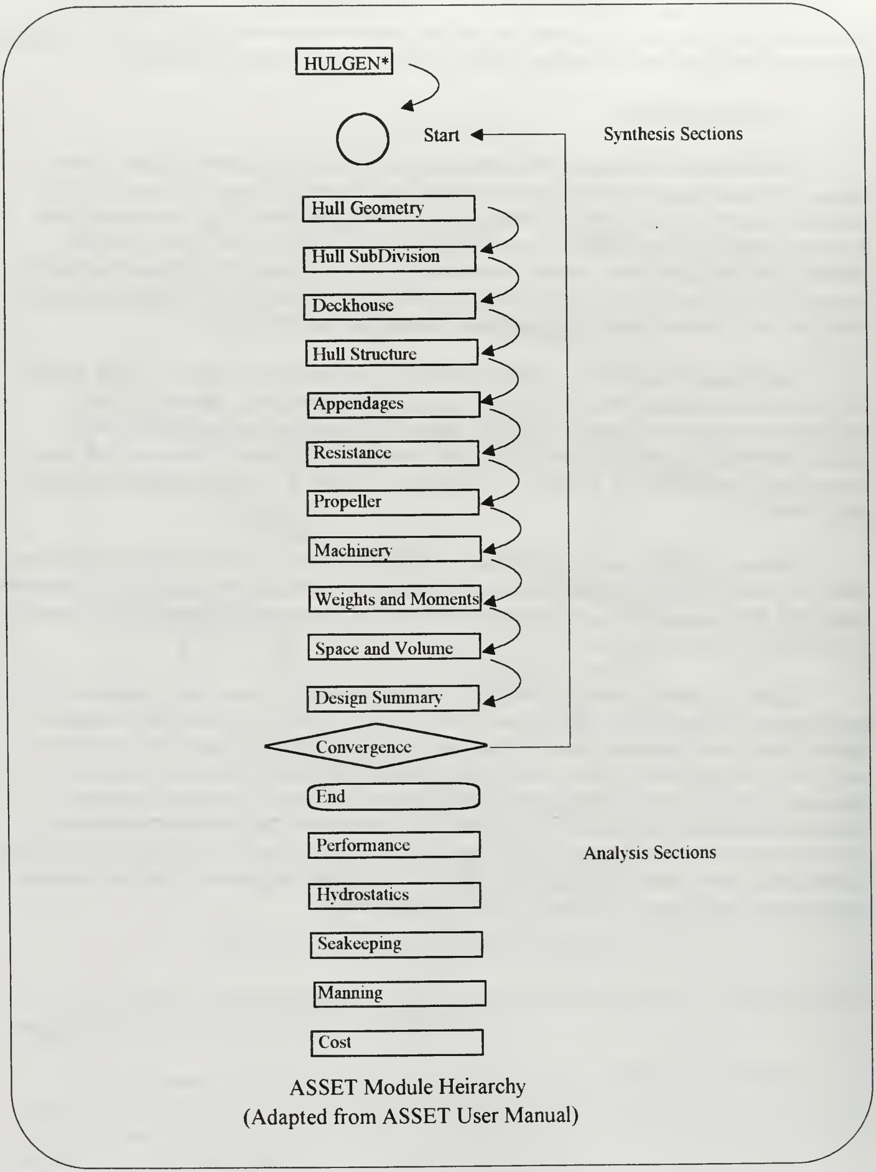


Figure 2-5 ASSET Module Hierarchy

2.3.1 Structural Design and Analysis

The ship's structure must be modeled in ASSET in order to achieve a synthesized and balanced ship. Yet, the algorithms and methods used by the HULL STRUCTURES Module of ASSET are not sufficiently robust to adequately determine structural sizes or perform structural analysis.

The ship's structure modeled in ASSET must be independently modeled and analyzed. MAESTRO, a rationally-based design and analysis tool, is chosen for this thesis. The details of the interface between ASSET and MAESTRO are discussed in Chapter 5.

2.3.2 Structural Cost Estimation

As discussed earlier in this chapter, ASSET relies on weight-based cost estimating techniques which are not sensitive to producibility enhancements. It is not sensitive to the cost of removing distortion which occurs during the fabrication of ship structures. The National Shipbuilding Research Program's "Development of Producibility Evaluation Criteria" (NSRP 0405) has been chosen as the model for this thesis. The computer program is significantly revised, yet the basis of it remains in the program. Details of this estimating program are developed in Chapter 4.

2.3.3 Structural Design, Concurrent Engineering Summary

The general concept suggested under the PODAC philosophy is used to achieve a satisfactory structural design. ASSET is used as the overall synthesis tool, while MAESTRO is used as the rationally-based structural analysis tool. The NSRP 0405 structural cost estimating computer program is modified to meet the necessities of integration with ASSET and MAESTRO.

After a hull structural design concept is modeled in MAESTRO, modified to meet the structural performance requirements, and its cost estimated, the weight of the hull structure is re-introduced to ASSET. If the hull structural design is a different weight than that of the synthesized/balanced ship in ASSET, the ship must be re-synthesized and re-balanced. If the hull form is revised, another loop through the structural analysis and cost estimating routine is performed. Iteration is performed until synthesis/balance is achieved.

After completing the synthesis/balancing, the new ship parameters are determined and measured. These parameters are used to determine the ship's performance compared to performance goals and thresholds. Performance is measured in many ways, including endurance, seakeeping, maximum speed, construction and fuel cost. If an improved performance is desired, and changes to structural design are expected to improved the performance of the new ship, the structural design is revised and the iteration to achieve the new ship concept is begun.

2.4 Summary

The rule-based structural design methods in ASSET do not always provide structures of adequate integrity. More sophisticated analyses are required. Rationally-based structural analysis, such as MAESTRO, is a superior method. This tool, while requiring more details of the ship than ASSET, is manageable at the concept design stage. Since to use rationally-based structural analysis, some level of detail is required, other analyses, such as cost and performance measurement are also enhanced. This allows a ship design to be conducted more simultaneously than the traditional design spiral.

The use of a process oriented design approach allows the designer to overcome some of the limitations of the traditional structural design approach and address the cost benefits of structural designs which have producibility enhancements. Addressing producibility and other fabrication issues is not possible with a weight-based cost estimating tool such as ASSET. Further, the traditional structural design approach does not provide a method to address producibility enhancements at the concept design stage. Among the items addressed late, if at all, are:

- fabrication and welding issues;
- producibility issues such as the use of parallel middle body and flat hull plate;
- distortion removal costs;
- scrap metal costs.

This thesis provides the methodology to incorporate rationally-based structural analysis, process oriented cost estimation and ship performance measurement.

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Chapter 3. Process-Based Estimate for Ship Construction Cost

3.1 Background of NSRP 0405 "Development of Producibility Evaluation Criteria"

The cost of construction is a major portion of the cost of any ship acquisition program. Of the cost of construction, roughly half is represented by labor cost (NSRP 0405). The primary objective of introducing "producibility" to a product is to reduce the man-hours necessary to produce the product.

Labor hours which can most directly be controlled by and through the design are those labor hours associated with producibility. A reduction in work content can be achieved in a number of ways: by designing simpler structures with fewer pieces; by designing structures which may be fabricated from maximum-sized material, which requires fewer pieces to account for, process, lift, etc.; and by a reduction in work content through a design which features a reduction in the material selection options. Fewer material selection options makes ordering, logistics, storage/sorting, marking and training easier and faster. The use of standardized components achieves many of the same reductions in work content.

Ship design has great leverage on the work content and labor hours associated with fabrication. Work content not only represents a significant part of the total ship acquisition cost, but also controls many indirect costs of ship construction. A reduction in work content is normally accompanied by a reduction in the time to fabricate the product. This results in shorter cycle time, and shorter cycle time requires an overhead cost to be carried by the shipbuilder for a shorter period to time. This reduction in overhead cost is passed on to the customer in the form of lower total ship acquisition costs.

For maximum effectiveness, producibility should be considered throughout all design stages. At each stage in the design cycle, decisions are made which prevent the introduction or inclusion of producibility improvements at a later stage in the cycle if the improvements were not considered from the beginning. Considering producibility issues from the beginning, as facilitated by the concurrent engineering approach, allows the design to be as "production-friendly" as possible, and prevents designs which are possible on paper but only possible on the shop floor at extreme cost.

3.1.1 Producibility Definition

To distinguish producibility from productivity, the authors of NSRP 0405 offered the following statement concerning "producibility" and how it is to be measured.

> "Producibility relates to the recurring expenditure of resources for constructing a product. Recurring cost is the measure of producibility. There is an inverse relationship between recurring cost and producibility."

This "definition" differentiates producibility cost from non-recurring cost. Since non-recurring cost may be prorated over several, or all, remaining units when determining total cost, it is a variable. On the other hand, recurring cost is essentially non-variant over multiple units, unless learning curve effects are considered. Where learning curve effects are included, the "curve" may be applied to the product separately or individually, allowing separate treatment of the results of the "learning". This theme will be developed in more detail in Chapter 8.

3.1.2 Cost Definition

This thesis addresses only the shipbuilders' required expenditure of construction manpower or other production resources necessary to produce the ship. In all cases, the measure of cost for labor will be man-hours, which are directly translatable to dollars (U.S.). The expenditures of other resources, such as structural plates and members as well as consumable materials, will be defined in dollars (U.S.).

The cost to produce a product includes the labor cost, material cost and the cost of operating the facilities used directly in the production of the product (welding machines, cranes, transporters, etc.). The facility operational, or overhead, costs are not included in this thesis.

3.2 NSRP 0405 Approach

"The objective of NSRP 0405 is to provide a mutually acceptable technique for use by Navy and industry in evaluating the construction cost of competing ship designs and design features, based on the work content of the design rather than on the weight of the design (NSRP 0405)."

A principal goal of NSRP 0405 was to obtain as much information as possible about the methods that were in use in the shipbuilding industry in the early 1990's for making producibility-related design decisions. After obtaining this information, an evaluation of the information was performed to identify criteria that is useful to make actual producibility decisions concerning the design. The most useful of these criteria were used to develop a computer model for estimating ship structural fabrication, piping installation and heating, ventilation and air conditioning installation.

The first task the authors undertook was to obtain and analyze the techniques that had been used to evaluate "producibility" changes during what were then current or recently completed NAVSEA design projects. These projects included the DDG-51, T-AGS-45, SWATH-TAGOS, T-AGOS-19, FFG-7 and the SSN-21. The authors met with NAVSEA personnel who had participated in or were then-currently participating in these projects.

The authors next visited and interviewed key personnel at several shipyards. The shipyards visited were: Bath Iron Works, Ingalls Shipbuilding Company, McDermott Inc., National Steel and Shipbuilding Company, and Newport News Shipbuilding and Drydock Company. There were also visits and interviews with key members of three Supervisors of Shipbuilding (SOS) offices; SOS Bath, SOS Newport News, SOS New Orleans (Amelia). Further, the authors organized and conducted a major workshop on this subject. The workshop was conducted in association with the 1990 Ship Production Symposium, held 21 August, 1990 in Milwaukee, Wisconsin.

Based on the expert opinion learned and obtained through these activities, the authors identified two different techniques for evaluating producibility in ship design. The method adapted for this thesis considers the work elements involved in the fabrication of a design and develops a cost estimate for building each competing design. The design which costs the least and which achieves the best producibility, as determined through the concurrent engineering approach, is the design chosen.

The authors of NSRP 0405 observe "...that all of the yards appear to use a relatively informal, unstructured system for evaluating most producibility changes. If it is 'obvious' that there will be a significant cost savings and the specifications do not have to be changed to accomplish it, personnel at the appropriate decision making level approve making the changes.

"One problem with this is that there seems to be little effort to evaluate the amount of saving in most such cases. Failure to recoup the man-hours or dollars 'saved' by reducing the man-hours allocated to the task in the development of work authorizations to the trades will reduce the likelihood that the projected savings will be reflected in the final man-hour expenditure. (NSRP 0405)."

Another problem with the attitude mentioned in the preceding paragraph has to do with perception and intuition. Perception and intuition often do not match measured and validated information. Occasionally, it is only once an individual is presented with the validated information that the "truth" of the issue is revealed and understood. There is no way to estimate how such informal decision making could be affecting producibility and the cost of acquisition without actually conducting a benefit/cost analysis. This issue is discussed further in paragraph 3.4..

The other method identified by the authors considers various criteria that affect the producibility of a design, determines the weighting factor to be applied to each criterion and then uses an analytical hierarchical approach to compare two or more design alternatives. The alternative which achieves the highest score will be the most producible, but the scores do not relate directly to cost.

The authors argue that the second method was developed (and in great detail in the document) "because it requires somewhat less information about specific production practices, and therefore can be utilized in cases where inadequate information exists to use the first technique." The analytical hierarchical approach is an excellent way to address the impact of design changes on the overall desirability of the design alternative as measured by its performance score. Yet, "the devil is in the details", and without knowing and addressing the available details of the design early, useful producibility and performance decisions may be discounted or exempted when they ought not.

3.3 Differences from Previous "Producibility" Studies.

The authors reviewed and used, as applicable, the results of several different ship "producibility" studies performed by NAVSEA during their preliminary or contract design stages. The studies themselves represented the expert opinion and analysis of hundreds of key shipyard and design agents. The ships whose producibility studies were reviewed were DDG-51, T-AO-187, AOE-6, T-AGS-45, T-AGOS-19 and the SWATH T-AGOS.

The authors' comments concerning the "producibility" aspects of each of these studies is illuminating and interesting reading. A summary of their comments follows:

Concerning the DDG-51 producibility study - This study identified 61 other studies as "producibility" studies. Of the 61, the authors report that 15 did not address costs either directly or indirectly. Further, the authors report that, "of the remaining 46, only 26 contained what could be termed a detailed analysis of the estimated costs. Finally, where included, the cost estimates frequently applied overall cost factors which were neither explained or supported..."

Concerning the T-AO-187 producibility study - An immature design was provided to six shipyards for a funded review. The shipyards submitted over 4000 comments in an unstructured format. Some of the comments were used to correct discrepancies in the immature design, but no major design changes were proposed or accepted.

Concerning the AOE-6 producibility study - The contract package was delivered late to the shipyards for an unfunded review. Only 200, or so, comments were submitted by the shipyards, and some were incorporated. However, none of the proposed major design changes submitted were incorporated because the design was set and the schedule established.

Concerning the T-AGOS-19 producibility study - Representatives from several shipyards provided numerous specific comments and suggestions during the Contract Design stage. The comments were a mixture of changes to design standards, design trade-offs and weight reduction approaches, plus an occasional true producibility comment. Only a limited number of comments were supported by quantitative analysis. "The quantitative analyses which were included were rudimentary, with very little detail useful for developing relationships between work content and man-hours or cost (NSRP 0405)."

Concerning the SWATH T-AGOS producibility study - "This report provides general producibility principles, makes 29 recommendations for change and includes an estimate of cost savings for making significant changes in the structural design of the ship. Many of the recommended changes, particularly in the area of machinery rearrangements, were incorporated into the design, since the members of the review team worked directly with the NAVSEA designers as the design was being developed (NSRP 0405)."

Concerning the T-AGS-45 Producibility Study - The report was divided into two main sections, a preliminary design review and a comparative analysis of three alternative mid-ship framing designs. The preliminary review made generic comments, overall observations, 22 suggested ship structure changes, 17 changes to the machinery and distributed systems, and 3 comments regarding other systems. There was no quantitative analyses made of the cost impact of any of the suggested changes or suggestions. The framing analysis was built on the analysis developed by the SWATH T-AGOS study, unfortunately, this report only included the calculations for some cost estimates, and some of the cost factors used therein were not explained in the study. The sources for several of the work measurement standards were not provided, and standards used in other tables were not referenced. However, the welding calculations developed in this study were used by NSRP 0405, included in the computer program presented in NSRP 0398, and used in this thesis.

Differences from Previous "Producibility" Studies - Summary.

The overall evaluation made by the authors of NSRP 0405 was that the producibility studies reviewed revealed few discrete useful producibility criteria. Most of the studies discuss trade-offs concerning the use of different equipment of greater or lesser capability, reductions in design requirements and other early stage design trade-off comments. All cost savings which were purported to be the result of adopting the suggested changes were weight based. The essence of all studies reviewed was that if no weight savings was recognized, that no savings could be anticipated.

So, the major difference between NSRP 0405 and those studies which had preceded it is that NSRP 0405 was quantitative, and applicable to the details of any production facility, and was not weight-based. Further, the criteria developed by NSRP 0405 was the foundation for the computer program published as "Producibility Evaluation Criteria Cost Estimating Computer Program - Manual", NSRP document number 0398.

3.4 NSRP 0405 Cost Estimating Computer Program

The NSRP 0405 Cost Estimating Computer Program is based on a bottoms-up, production engineering approach. The technique requires a good understanding of the actual production practice proposed to be used. Once this production practice is known or assumed, the approach is equally effective at estimating small fabricated parts as it is estimating erection blocks. The technique can be used to determine the cost differences between several design alternatives if the fabrication techniques and methods are well known. Additionally, since often only differential cost estimates are necessary, the technique can be used to obtain such estimates if the fabrication particulars can only be estimated.

The approach considers how the design is to be built and estimates the man-hours expended during each identifiable step in the fabrication process of the interim product. The NSRP 0405 program estimates the direct and indirect labor hours expended and the material costs for the interim product.

The authors of NSRP 0405 note "These cost estimating computer programs represent the first step in developing a standardized format and methodology for estimating cost of ship construction and repair. As such, the programs are intended to establish a common language between shipyards, Supervisors of Shipbuilding, NAVSEA, ship owners and design agents. Additional programs will be required to expand the coverage to those other aspects of the work normally performed in a shipyard (which are not covered by the NSRP 0405 computer program). These cost estimating forms are only the first step in an evolving process to develop a standardized method of estimating cost in evaluating the producibility aspects of alternate designs.

"The cost factors used in the cost estimating computer program are based upon data and engineering standards obtained from various sources. The contributions to this effort by the U.S. Naval Shipbuilding Scheduling Office are particularly appreciated. It is fully recognized, however, that the data contained in the current version of the program provide only a reasonable starting point and that revisions and expansions can be expected after other organizations review and apply the program (NSRP 0405)".

Two specific validations of the use of the concept are described in NSRP 0405, one for pipe bending versus pipe joining and another for the production of manholes and handholes. A comparison of an alternate design and the as-fabricated design were used for the validation. The source of the "true" data was not disclosed.

An attempt to refine the factors used by the cost estimating computer program was published in "Product Oriented Design and Construction (PODAC) Cost Model Development, Final Report (DRAFT)", dated May 1995 (Bunch). Further details of the PODAC approach are discussed in paragraph 3.5

3.4.1 NSRP 0405 Computer Program - Basic Concept

The basic concept is to define the steps necessary for producing an interim product at a level of detail which allows adequate description of fabrication, yet does not repeat the detail design. Then, based on engineering standards and shipyard fabrication experience, apply factors which estimate the man-hours required for each specific task, process or activity. Factors define man-hours per work unit; where work units are "per foot," "per square foot." or "per piece."

The factors estimate the work content per work unit necessary to perform each step using a key characteristic or parameter of the interim product as the independent variable.[6] For example, the NSRP 0405 computer program for structural steel uses plate thickness as the key variable. A more sophisticated analysis might use multiple attributes to develop the work content.[7] For this analysis, a single parameter was also used, but not always plate thickness. When a thickness is required in the spreadsheet, it is the plate or structural member's web thickness that is used.

The factors used to estimate the work content take into account whether the work is accomplished during the most efficient work stage or at a later point in the fabrication process.

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6 The factors used to multiply against the key variable are determined from engineering standards, expert opinion and other data.

7 This would make the process much more robust. Yet since data is only available from shipyards, it is always difficult to obtain, and once obtained and the weighting factors developed, validation from shipyards would likely be equally difficult.

The quantity of work performed to fabricate the interim product is determined as the sum of the individual work routines performed. The total man-hours expended is converted to labor cost, accounting for direct and in-direct labor. The material cost is added to the total labor cost. Where actual material costs are available, they are used; elsewhere weight-based or other estimating material cost techniques are used. Again, the more fidelity the interim product model holds, the more accurate the cost estimate. The method used to estimate material cost is found in Chapter 4.

3.4.2 NSRP 0405 Computer Program - Description

The NSRP 0405 Cost Estimating Computer Program is organized in a spreadsheet. An example of one of the spreadsheets is provided in Table 3-1.

The spreadsheet is organized to determine the cost of the interim product if all processes are performed at the desired stage of production, and to determine the cost if individual processes are performed at a later, more costly, stage of production. This organizational pattern makes the spreadsheet particularly useful for shipyard design and production engineers to conduct work schedule planning.

The authors of NSRP 0405 prepared spreadsheets for hull structure, heating, ventilation and air conditioning (HVAC), electrical and piping installation. The central portion of each spreadsheet includes the same column headings: Work Process, Work Units, Process Factor, Unit Amount, Actual Stage, Standard Stage, Actual Factor, Standard Factor, and Man-hours Required.

A brief description of each column is provided in Appendix 1.

3.4.3 NSRP 0405 Computer Program - Summary

The NSRP computer model is quantitative, and presents a standard approach to estimating several shipbuilding activities common to all ships. In application, its quantitative nature prevents informal decision making, since details and analysis are required. The spreadsheet layout presents a standard form, where elements and work processes and practices may be tailored to match individual design or shipyard needs.

The layout is not oriented, however, to facilitate easy assessment of design trade-offs. An improvement to the layout which facilitates design trade-off assessment is presented in Chapter 5.

Table 3-1 Original NSRP 0405 Spreadsheet

COST ESTIMATING FORM FOR STRUCTURAL WORK									
PROJECT:	"TITLE"								
FILE :	XYZ123.WK1								
MATERIAL:	HTS		THICKNESS :	0.5	INCHES				
	WORK PROCESS	WORK	PROCESS	UNIT	ACTUAL	STANDARD	ACTUAL	STANDARD	MNHRS
		UNITS	FACTOR	AMOUNT	STAGE	STAGE	FACTOR	FACTOR	REQ'D
			(MNHRS/)						
			(WORK UNIT)						
1	OBTAIN MATERIAL	SQ FT	0.1	0	1	1	1	1	0
	RECEIPT & PREP								
2	FLAME CUTTING								
	AUTOMATIC	LN FT	0.05	0	1	1	1	1	0
	MANUAL	LN FT	0.09	0	2	2	1.5	1.5	0
3	EDGE PREP-GRINDING								
	FLAT	LN FT	0.04	0	1	2	1	1.5	0
	VERTICAL	LN FT	0.06	0	2	2	1.5	1.5	0
	OVERHEAD	LN FT	0.08	0	2	2	1.5	1.5	0
4	SHAPING								
	BREAK	BEND	0.48	0	1	1	1	1	0
	ROLLING	PIECE	1.2	0	1	1	1	1	0
	LINE HEATING	PIECE	10	0	1	1	1	1	0
	FURNACE	PIECE	15	0	1	1	1	1	0
	PRESS	PIECE	0.02	0	1	1	1	1	0
	MACHINING	CU IN	0.02	0	1	1	1	1	0
5	FIT UP & ASSEMBLY	LN FT WELD	0.56	0	2	2	1.5	1.5	0
6	WELDING, AUTO /MACHINE								
	FILLET	LN FT	0.07	0	2	2	1.5	1.5	0
	BUTT	LN FT	0.48	0	2	2	1.5	1.5	0
7	WELDING, MANUAL								
	FILLET								

	DOWNHAND	LN FT	0.34	0	2	2	1.5	1.5	0
	VERTICAL	LN FT	0.51	0	2	2	1.5	1.5	0
	OVERHEAD	LN FT	0.68	0	2	2	1.5	1.5	0
	BUTT								
	DOWNHAND	LN FT	1.3	0	2	2	1.5	1.5	0
	VERTICAL	LN FT	1.95	0	2	2	1.5	1.5	0
	OVERHEAD	LN FT	2.6	0	2	2	1.5	1.5	0
8	MARKING	PIECE	0.1	0	1	1	1	1	0
9	HANDLING								
	STORAGE	PIECE	0.1	0	2	2	1.5	1.5	0
	TRANSPORT	ASSY	5	0	3	3	2	2	0
	LIFTING	ASSY	5	0	4	4	3	3	0
10	SURFACE PREP								
	BLASTING	SQ FT	0.1	0	3	3	2	2	0
	GRINDING	FOOT	0.2	0	3	3	2	2	0
11	COATING	SQ FT	0.1	0	3	3	2	2	0
12	TESTING								
	DYE PENETRANT	FOOT	0.25	0	2	2	1.5	1.5	0
	AUDIOGAGE	FOOT	0.5	0	2	2	1.5	1.5	0
	X RAY	FOOT	0.5	0	2	2	1.5	1.5	0
	TOTAL TRADE MAN-HOURS								0
	TRADE SUPPORT MAN-HOURS (35% OF TRADE MAN-HOURS)								0
	TOTAL PRODUCTION MAN-HOURS								0
	LABOR COST (MAN-HOURS X MNHR COST)				$20.00				$0
	MATERIAL COST (FROM MATERIAL SCHEDULE)								$0
	TOTAL COST								$0

3.5 Product Oriented Design and Construction Cost Method

The fundamental goal of Product Oriented Design and Construction (PODAC) is similar to that presented by the NSRP 0405 computer program. That is, to construct a cost estimating system which relies on process-based information which is applicable across a wide range of vessel types.

The stated goal of the PODAC study was to develop a cost estimating system based on "a logical build-up of predetermined product models with associated material and process costs. The concept was a combination of 're-use' modules and 'zonal product' modules. A re-use module is any part of a ship such as a geographic area (machinery space, superstructure, bow, etc.), construction assembly or interim product to which costs can be ascribed, either by calculation or by return cost. This module is then 're-used' in another ship design, carrying with it a complete cost definition that is used as one element of the new ship's cost estimate. A zonal product module is a unique portion of a new ship design that can be broken down to some level of interim products for which costs can be calculated or to which re-use module costs can then be applied. (Bunch, PODAC)."

Therefore, the PODAC system desires to develop a fully integrated cost estimating system, whereas, the NSRP 0405 had a less ambitious goal. Although, if both were implemented in every area of ship production, the same end would likely be achieved.

The PODAC system utilizes the NSRP product work breakdown structure (PWBS) (NSRP 0117) as the basic framework for developing its Estimating Breakdown Structure (EBS). Further, PODAC relies on existing data bases from which to translate data. The PODAC draft validated structural assemblies, SWBS 100, based on a PD-337 MARAD preliminary sealift design. The PD-337 is a Commercial Cargo Ship for Sealift in the Year 2000.

The PODAC system allows top-down or bottom-up cost data development, which in theory, arrive at the same cost estimate. The top-down approach replicated the NAVSEA structural cost estimates, and sequentially broke the estimates down to the ship's major block assemblies. This produced an estimate for every major block assembly which matched the NAVSEA estimate. The bottom-up approach estimated a major block assembly by summing the cost of all interim products used for the major block.

The study showed that neither approach is inherently superior, and both require more development. Both are inferior to the process-based approach used in NSRP 0405.

3.5.1 PODAC - Concept Formulation

The authors (Bunch et al.) of the PODAC study conducted an extensive literature search. They determined that there were only seven viable cost estimating methods in existence. They summarized the methods in a table. Based on the author's collective wisdom and experience, they determined that of the seven viable options, that only two methods were compatible with the PODAC philosophy: Engineering and Re-Use/Module. The PODAC author's comparison of these two methods is replicated below as Table 3-2.

Table 3-2 PODAC Study Favored Cost Estimate Methods

Type of Cost Estimate	**Precision**	**Cost**	**Time**	**Ability to Reflect Production Changes**	**Ability to Reflect Design Changes**	**Data Base Cost**
Engineering	High	Very High	Slow	Yes	Yes	Large
Re-Use / Module	High	Low / Moderate	Quick / Moderate	Yes	Yes	Large Startup

While the re-use/module cost estimate method has the potential for repeatability, the fact that the method is based on using a standard or near-standard package throughout the design does not immediately support the authors' assertion that production and design changes are easily facilitated.

The authors of the PODAC study made the following comments concerning the engineering method:

> "The detailed engineering methodology involves a detailed examination of the materials and processes required to fabricate and assemble the completed product. The estimator literally builds the product in his mind, listing the materials and resources required at each step of construction. At the end of the process, the listed needs are summed to a total. Advantages of the detailed engineering estimate are its accuracy, its ability to reflect design and production changes, and the ability to be effectively utilized in a PODAC system. Disadvantages include the high cost of the estimate, and the longer time required to formulate the estimate. Also, the cost of database configuration will be larger, because of the need to have files that link process requirements to product configuration."

The advantage of this method is its inherent flexibility and ease of conducting cost estimates coincidentally with engineering analysis.

The authors of the PODAC study made the following comments concerning the Re-Use/Module method:

> "The final technique. cost estimating based on the concept of re-use modules. can supply estimates with a low margin of error, and do so quickly. Also, the system has the ability to reflect production and design changes in the product, and can be used in a PODAC system. The main disadvantage of the concept is that the database must be configured to show modules and re-use elements. This disadvantage is somewhat offset by indications that the Navy is moving toward implementing databases of this type into its system." [8]

A disadvantage with this method is that it requires re-use modules, and does not have inherent flexibility. Further, the process makes it more difficult to access the producibility of design alternatives. Re-use modules are suggested to be models at the following levels:

- parts fabrication;
- assembly;
- sub-block assembly;
- block assembly;
- grand block assembly;
- final erection.

The essence of the re-use method is describing a design at each of these levels in order to estimate the man-hours and material costs. Then, once these standard modules are validated, linearly scaling them to new weights as the design changes. Therefore, this system is weight-based at several fabrication or interim product levels instead of weight-based by SWBS Group. Further, there is nothing inherent in the interim product description which provides a measure of producibility or cost savings as a result of producibility enhancements, unless different re-use modules or zonal product models are used which reflect these producibility enhancements.

The PODAC authors determined that the best method would be a "model based on the concept of a logical build-up of predetermined product modules with associated process an material costs". Such a method would allow coding of all processes, materials, re-use and zonal modules, which would make the system easy to maintain, very fast to use, and highly accurate.

3.5.2 PODAC - Concept Description

The PODAC model is based on the concept of re-using known information or previously determined information adapted to the current application. The use of "predetermined product

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[8] The PODAC did not expound upon or define the Navy database implementation. The study suggested that the Affordability Through Commonality (ATC) program, and the Advanced Surface Ship Machinery Program (ASMP) were indicators of the direction the Navy intended to pursue, and would ultimately establish a family of common components across all ship types. The PODAC author suggested, without supporting documentation, that "the Navy will ultimately put into place a re-use coding system that will further support concepts of modular design and construction".

modules with associated process and material costs" is key to its implementation. The modules are a combination of zonal product modules and re-use modules.

"A zonal product module is a new or significantly different design for which costs must be calculated. The calculations are performed using process estimators and direct material costs to calculate the cost of each element that comprises the zonal product module. The cost of the zonal product module is the summation of the costs of its components. (Bunch, PODAC)." This sounds similar to the approach suggested by NSRP 0405, yet the "components" mentioned by Bunch, et al. are not described in detail as in the process-based method, but are more like groups of similar components which are grouped together.

Like the authors of NSRP 0405, Bunch et al. suggest that using the PWBS and group technology, the ship may be divided into a series of interim products. Under the PODAC philosophy, at each stage of construction there are "process parameters" which are applied dependent on the level of difficulty or construction complexity. These process parameters are also encoded into the PWBS classification. The result is a classification and coding structure that permits assignment of a product and process to each distinct interim product in the ship construction process.

As an example of the process, certain PD-337 hull blocks were used to develop a zonal product module cost in the PODAC study. As Bunch, et al. has suggested, "Engineering judgment and ship construction experience were used to determine a logical set of interim products and an assembly sequence. The material costs were summed directly from the bill of materials, while interim product production costs were estimated by applying process factors (or cost estimating relationships) to each process involved in constructing the interim product and integrating them into a hull block."

As can be seen in this example, the zonal module cost estimating philosophy is identical to the "Engineering" cost estimating method. For some reason, the authors of the PODAC study implied that zonal module cost estimating is completely different from "Engineering" cost estimating.

"A re-use module is a product module for which actual costs are available from an earlier construction experience. (Bunch, PODAC)."

The key to PODAC's success is the integration of re-usable "things" in the ship design, where the things are identical across ship classes. Among such "things" discussed in the study are ATC's habitability spaces, sanitary spaces and machinery pallets. These are self-contained interim products, which once actual costs are determined, become known items in all design areas: cost, weight, size, etc.

Bunch et al. suggest that re-use modules could be general in nature. A standard stiffener which is repeated throughout the design is offered as a case in point. "The processes that add value to that stiffener during fabrication, such as stripping a flange off an I-beam, never change and vary linearly with weight (or length). The stiffener can become a re-use module in a detailed cost model, with a linear multiplier applied to reflect size variations. (Bunch, PODAC)."

Bunch et al. build on the stiffener example. They suggest the following. "A particular type of stiffened panel is used repeatedly for bulkheads or decks. The processes involved in fabricating the parts and assembling them into stiffened panel are always the same in every application of this panel, with a linear variation associated with weight, size or number of stiffeners. The costs of fabricating and assembling the stiffened panel are calculated and the sum cost becomes a re-use module in the ship cost estimate. (Bunch, PODAC)."

3.5.3 PODAC - Software Description

In order to integrate such a system, the PODAC study determined that a computer software would be necessary. The commercial software package, PRICE-H, by Martin Marietta, was chosen from four software packages reviewed.

PRICE-H utilizes a hierarchical, outline type structure that closely resembles PWBS hierarchy. The program runs on a personal computer (PC). The program was developed for an electronic manufacturing system producing relatively high cost electronic parts. It was designed for a manufacturing process which produced many parts, each with fast fabrication time and where quick process re-configuration times were expected.

The software has a "calibration" routine which allows the estimator to calibrate user-defined complexity factors used in the program to produce cost estimates that are known to be accurate. Additionally, it uses actual data to compare the cost of real production to that of predicted production for alternative designs or alternative interim products.

PRICE-H relies on expert knowledge of such things as "engineering complexity", "mechanical reliability" and "manufacturing complexity of the structure" among many others. Values for these and other parameters range from unity to ten thousand, and may have required (or assumed) accuracy on the order of one in ten million (or 0.0000001). So a number such as 12,345.1234567 might expected to be used as a parameter or factor.

Specifically concerning "manufacturing complexity of the structure", the element cost was reported to be extremely sensitive to changes of this parameter. A change of 0.001 was reported to result in a 5% to 10% change in production cost, a change of 0.01 causes a 10%-35% change in production cost and a change of 0.1 results in a change of 50%-100%.

3.5.4 PODAC - Comparison with NSRP 0405

One of the two uses of the PRICE-H software was to conduct a bottoms-up cost estimate, beginning with individual plates and structural members. This estimate was purposefully similar to that used by NSRP 0405, it was hoped that the PRICE-H estimate would provide some sort of "validation" of NSRP 0405 methods.

Using the process factors provided by NSRP 0405, a bottoms-up cost estimate for Block 13A of PD-337 was estimated. When compared to the top-down PRICE-H approach, the bottoms-up approach was nearly twice as costly. This discrepancy caused concern for the PODAC authors.

Bunch, et al., asserted that the NSRP 0405 process factors are overly conservative, especially for welding processes. In Appendix B of the PODAC study is a description of a Process Factor comparison among several publications. These publications include "The Design and Planning Manual for Cost Effective Welding, Submerged Arc Weld process for Joint Design 1 and 3" (NSRP 0339), the Lincoln Electric Company Procedure Handbook of Arc Welding, and Walker's Building Estimator's Reference Book. Additionally, the blasting and painting factors from "Labor Standards Application Program, Blast and Paint Shops, Final Report" (NSRP 0235) are suggested to be used instead of those provided by NSRP 0405.

A comparison of some process factors is presented in Tables 3-3 through 3-5.

Table 3-3 Comparison of Manual Burning Process Factors: Mild Steel (man-hour/linear foot)

Plate Thickness (inches)	PNS - Normal	PNS - Difficult	PNS - Extreme Difficulty	NSRP 0405	PODAC Study
0.13	0.09	0.12	0.14	n/a	0.01
0.38	0.09	0.12	0.14	0.09	0.01
0.5	0.09	0.12	0.14	0.09	0.01
0.75	0.12	0.14	0.16	0.12	0.01
1	0.16	0.19	0.23	0.16	0.1
1.13	0.17	0.21	0.24	0.17	n/a
1.5	0.18	0.23	0.26	0.18	n/a
2	0.23	0.27	0.32	0.23	n/a
3	0.26	0.31	0.34	0.26	n/a
4	0.28	0.34	0.4	0.28	n/a
5	0.32	0.38	0.4	0.32	n/a

Table 3-4 PODAC Study: Cutting and Welding Process Factors (man-hour/linear foot)

Plate Thickness (inches)	Flame Cutting Manual	Flame Cutting Automatic	Auto Fillet Welding	Auto Butt Welding	Manual Butt-D* Welding	Manual Butt-V* Welding	Manual Butt-O* Welding
0.13	0.01	0	0.01	0.01	0.01	0.02	0.02
0.25	0.01	0	0.01	0.01	0.01	0.03	0.03
0.38	0.01	0	0.01	0.01	0.02	0.06	0.06
0.05	0.01	0	0.02	0.01	0.03	0.1	0.11
0.75	0.01	0.01	0.02	0.01	0.07	0.23	0.23
1	0.01	0.01	0.03	0.02	0.11	0.4	0.46

* "D" - Downhand; "V" - Vertical; "O" - Overhead. For further description of the differences between these welding orientations, see Appendix 2.

Table 3-5 NSRP 0405: Cutting and Welding Process Factors (man-hour/linear foot)

Plate Thickness (inches)	Flame Cutting Manual	Flame Cutting Automatic	Auto Fillet Welding	Auto Butt Welding	Manual Butt-D* Welding	Manual Butt-V* Welding	Manual Butt-O* Welding
0.25	0.09	0.05	0.04	n/a	0.62	1.24	1.86
0.38	0.09	0.05	0.05	n/a	1	1.67	2.33
0.05	0.09	0.05	0.07	0.48	1.3	1.95	2.6
0.75	0.12	0.07	0.08	0.58	1.8	3.6	5.1
1	0.16	0.07	0.09	0.7	2.4	5.1	7.8

* "D" - Downhand; "V" - Vertical; "O" - Overhead. For further description of the differences between these welding orientations, see Appendix 2.

The PODAC study addressed only cutting, welding and blasting/painting process factors, whereas NSRP 0405 addressed many more factors. The process factors suggested by Bunch, et al., are correct for actual work performed, but they do not include work set-up, equipment adjustment, maintenance and set-up, or other real-life factors. To use the process factors suggested by the PODAC authors, another metric is needed to account for the "other" activities which legitimately consume workers' time. In the PODAC study, the authors do not describe how they account for these other legitimate activities.

Table 3-6 presents a comparison of the man-hours consumed in each process category for a DDG-51 midship section calculated using the original NSRP 0405 factors and using the fabrication process factors suggested in the PODAC study. The large reduction in man-hours for those processes discussed in the PODAC study is very apparent, and indicates the problem with modeling only the "actual" work associated with some processes and not the others.

Table 3.6 Man-hour Estimates for DDG-51 Midship Section

Process	Original	PODAC
Matl Rec&Prep	781	781
Auto Flame Cut	56	3
Manl Flame Cut	41	3
Edge Prep Flat	250	250
Edge Prep Vert	3	3
Edge Prep Ovhd	0	0
Shape - Roll	248	248
Shape - Line Ht	910	910
Fit-Up & Assembly	2,107	2,107
Distortion	486	486
Auto Weld - Fillet	95	18
Auto Weld -Butt	461	8
Man Weld - Fillet Down	770	770
Man Weld - Butt Down	1,373	29
Man Weld - Butt Vert	442	17
Man Weld - Butt Ovhd	0	0
Marking	36	36
Store	39	39
Transport	1,940	1,940
Lift	1,940	1,940
Blast	1,562	47
Coating	1.562	37
Direct Labor	15,102	9,672
Total Labor	18,877	12,090
manhr/lton=	363	233
manhr/lton (w/o Distortion)=	349	218
(C+W+F)/Total Labor =	0.45	0.46
Cutting+Welding+Fabrication=	6,793	4.402
Scantling Cost	67,608	67,608
Scantling $ / Labor $	0.1	0.15

** Labor Rate = $37.5 per hour. See Chapter 5

3.6 Summary

The use of software which is modular and hierarchical is very appealing. The fact that a particular software, such as PRICE-H, has been successfully used in generally similar application provides some level of confidence that its application to shipbuilding is possible. The fact that PRICE-H has a method of self-calibration makes particular software product particularly attractive.

However, shipbuilding is a low through-put and slow cycle-time business. Plus, as established in Chapter 1, shipyard cost details are difficult to determine, and not known to be highly accurate. Furthermore, additional factors which account for worker man-hours which are not directly consumed with grinder or welding rod in-hand are not known and more difficult to estimate than "actual work" processes. Therefore, the fact that there are so many factors or parameters which require high accuracy makes the real application of a system such as PRICE-H, by itself, questionable.

The PODAC study failed to consider that the design must be modeled twice. Once for engineering analysis and second for cost estimation. The process factors suggested by the PODAC study estimate the time required for only "actual" work, i.e. only the time from weld arc ignition to exhaustion per weld pass. The PODAC study does not suggest how to estimate the time workers are performing legitimate activities and progressing towards their goal, yet are not "actually" welding, grinding, edge preparing, etc. To account for this "other" time, a "new process factor" must be determined. This "new process factor" essentially amounts to determining the productivity of a shipyard's structural group (welders, grinder, painters, etc.). This is certainly not a metric which any shipyard would be eager to publish or disclose.

The PODAC approach requires the same level of detail for many cost estimation applications, e.g. zone modules, as does an "Engineering" approach. The "re-use" modules require the use of characteristics of shipbuilding which are vaguely or immaturely defined, e.g. "manufacturing complexity of the structure", and requires such parameters to be highly accurate in order for the cost estimate to be accurate. The PODAC approach is strictly a cost estimation, and provides no other analysis or performance predictive capability.

The NAVSEA 017 estimates are based on evaluations of an "average" U.S. shipyard's practices, whereas the PODAC study is based on "current world class" practices. It is generally recognized that "current world class" practices are roughly twice as efficient as U.S. shipyard practices (SSC-377). This generally explains the discrepancy identified by Bunch, et al..

However, the comments made by the PODAC authors did suggest that the process factors suggested by NSRP 0405 be reconsidered. More discussion of this matter is found in Chapter 7.

The PODAC study approach does account for the direct work content of cutting, welding, and fabricating, but does not provide a clear method of accounting for the other legitimate tasks (set-up, equipment maintenance and re-adjustment, coffee breaks, etc.) performed by the craftsmen/artisans. Further, the direct work content labor hours suggested by the PODAC study do not cover the entire range of material types covered by the NSRP 0405 look-up tables, leaving gaps in the application suggested by the PODAC study.

Given the results of this comparison, an engineering approach similar to that of NSRP 0405 is more appropriate than the PODAC approach for the concept design.

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Chapter 4. Material Cost Estimation Method

NSRP 0405 does not specify or suggest any method to estimate material costs. Three methods are considered here for use associated with process-based cost estimation. These are three-digit weight-based, the Kriezis algorithms, and the use of shipyard provided information.

4.1 SWBS-Based Material Cost-per-Weight Method

The PODAC study published a cost estimate for MARAD PD-337 prepared by Naval Sea Systems Command Code 017. This estimate was performed using their in-house cost estimating relationships. They provided a three digit SWBS cost breakdown for Groups 100 through 900 inclusive. The only three digit SWBS material cost estimates applicable to this thesis are SWBS Group 110 (shell structure), 130 (hull Decks) and 140 (hull platforms and flats). Table 4-1 presents the NAVSEA Code 017 cost estimate for these selected SWBS Groups.

Table 4-1 NAVSEA Code 017 Cost Breakdown for MARAD PD-337

SWBS	Weight (lton)	Man-hours	Labor $ (,000)	Mat'l $ (,000)*	Total $ (,000)	Manhr/lton	$/lb*
110	3,987.7	275,468	6,575	3,385	9,960	69.08	0.38
130	1,345.64	88,855	2,121	0.5	3,210	66.03	0.36
140	1,783.69	157,643	3,763	1,942	5,705	88.38	0.49
100 average	10,785	867,063	20,696	12,584	33,280	80.4	0.52

* The year the material cost were estimated was not reported, but assumed to be 1995, the year the PODAC study Draft Report was published.

The average material cost per pound for SWBS Groups 110, 130 and 140 is $0.402/lb. This provides a single weight-based factor to estimate material costs. However, it does not allow for process-based cost estimation since it is not sensitive to the nature (plate or stiffener) or structural shape of the material. Nor does it differentiate between material type, thickness or structural shape configuration.

4.2 KRIEZIS Method

Kriezis, in his paper titled "Standardization in Ship Structural Design" (Kriezis), provides curves which predict the cost per weight of individual structural plates and shapes as a function of a single parameter. For plates, the parameter is the thickness, for shapes, the parameter is the cross-sectional area.

Parametrics for these curves (Prof. Brown, MIT) are directly applicable to estimate HTS material costs for SWBS Groups 110, 130, and 140. One formula estimates the cost of plate and another to estimates the cost of stiffeners, frames, girders and longitudinals.

The algorithms require the application of an inflation rate. The formulation of the inflation factor is presented in Figure 4-1.

Inflation:

Base Year: $Y_B := 1995 \qquad iy := 1 .. Y_B - 1989$

Average Inflation Rate (%) (from 1989) $\quad R_I := 3. \qquad F_I := \prod_{iy} \left(1 + \frac{R_I}{100}\right) \qquad F_I = 1.194$

Figure 4-1 Determination of Inflation Factor

Figure 4-2 presents the formula for estimating plate material cost per metric ton; Figure 4-3 presents the cost per pound (y-axis) as a function of thickness (x-axis) for the formula presented in Figure 4-2.

Standard HTS($BY): $\quad C_{PSHTS}(t) := \left(840 \frac{dol}{mt} - 4.5 \frac{dol}{mt \cdot mm} \cdot t\right) \cdot F_I \qquad C_{PSHTS}(.5 \cdot in) = 0.424 \cdot \frac{dol}{lb}$

Where "t" is the plate thickness.

Figure 4-2 Standard HTS Plate Cost Estimate

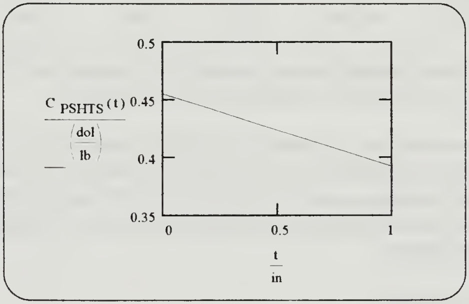

Figure 4-3 Cost per pound for HTS Plate

Figure 4-4 presents a formula, based on the Kriezis curve, for estimating stripped "I-T" shapes per metric ton; Figure 4-5 presents the cost per pound (y-axis) as a function of thickness (x-axis) for the formula presented in Figure 4-4.

Double Web Tee, I-T ($BY): $\quad C_{TDWHTS}(A) := \left(2200 \frac{dol}{mt} - 2.05 \frac{dol}{mt \cdot cm^2} \cdot A\right) \cdot F_I \qquad C_{TDWHTS}\left(21.8\, in^2\right) = 1.035 \cdot \frac{dol}{lb}$

Where "A" is the cross-sectional area of the de-flanged "T-beam.

Figure 4-4 "I-T" (De-Flanging) Stiffener Cost Estimate

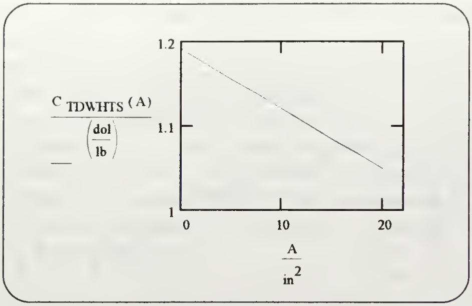

Figure 4-5 Cost per Pound for HTS "IT" Stiffeners

Using the Kriezis method, process-based cost estimation is possible and easily applied to a spreadsheet.

4.3 Shipyard Provided Information

Bath Iron Works (BIW) was contacted concerning the cost of steel. They provided the cost for MIL-S-22698 Grade DH-36 plates (as a function of thickness). Table 4-2 presents these cost per pound for these plates.

Table 4-2 Cost per Pound for DH-36 Plates *

Thickness	S	S/lb
1/8	0.13	0.49
3/16	0.19	0.48
1/4	0.25	0.47
5/16	0.31	0.47
3/8	0.38	0.47
7/16	0.44	0.47
1/2	0.5	0.45
9/16	0.56	0.45
5/8	0.63	0.45
11/16	0.69	0.42
3/4	0.75	0.42
13/16	0.81	0.42
7/8	0.88	0.4
15/16	0.94	0.4
1	1	0.39

* Mr. Cheetam could not specify whether these figures are for normal or 1/2 tolerance plate.

Figure 4-6 presents the information of Table 4-2 in graphical format

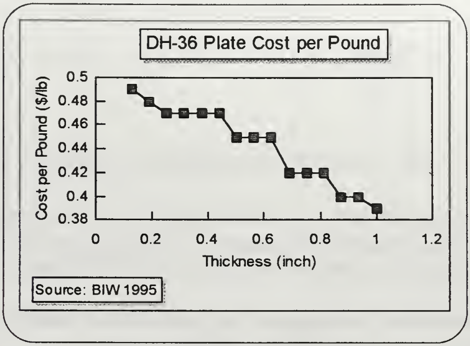

Figure 4-6 BIW Plate Costs

A comparison of the plate cost estimates using the BIW information and the Kriezis method is found in Figure 4-7. While the cost estimates converge for plate thicknesses above roughly 5/8 inch, for the thicknesses concerned here, the Kriezis estimates are as much as 10% low.

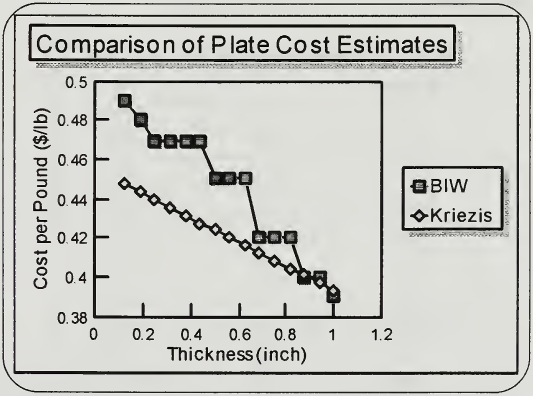

Figure 4-7 Comparison of Plate Cost Estimates

Additionally, BIW provided the costs for MIL-S-22698 Grade AH-36 structural shapes. Table 4-3 presents these cost per pound for these shapes.[9]

9 Again, the Distributor price is used since it includes the cost of delivery.

There are two basic methods of creating a "T-beam" for use in naval vessels. The first method requires cutting off the flange along either side of the beam's web. This produces a one deep-web T and two pieces of scrap. There is 25% wastage in stripping I-T shapes, possible distortion and the possibility for mis-shaped or poorly formed final products using this technique (Blomquist). Figure 4-8 presents some common problems associated with de-flanging. While this process is possible to be conducted by machine, based on expert opinion at the shop floors of BIW and NASSCO, the machines are prone to failure and are maintenance intensive, therefore the scribing (marking) and cutting is performed manually. The structural shapes used by BIW are "I-T" beams. The second method to construct a "T-beam" is to cut an "I-beam" down the middle, thereby producing two "Ts" with a single cut.

Both "I-Ts" and "ITs" are described on DDG-51 Detail Design, yet shipbuilders' discretion to choose is allowed for production and cost reasons.

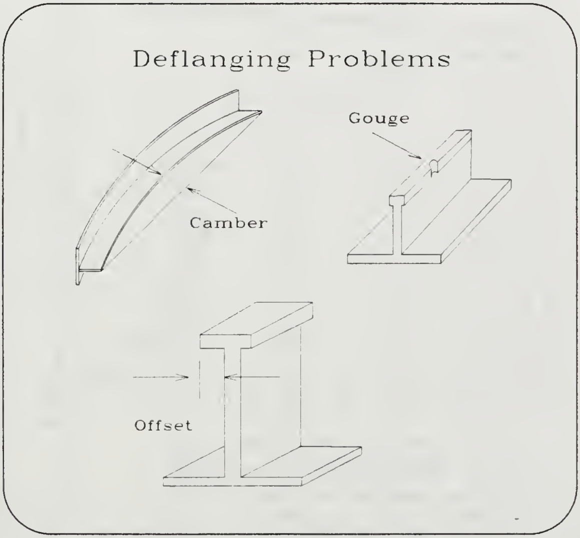

Figure 4-8 De-flanging Problems

To account for the waste associated with de-flanging I-beams, the area of each full I-beam is reduced by 25%. The cost per pound using the "corrected area" since weight scales linearly with area. The cost of de-flanging is discussed below.

Table 4-3 AH-36 Structural Shape Costs (BIW)

Shape	Area	$/lb	Area corrected for wastage	$/lb corrected for wastage
W6X9	1.81	0.38	1.36	0.48
W8X10	2.11	0.4	1.59	0.5
W8X13	2.8	0.4	2.1	0.5
W8X18	3.53	0.43	2.65	0.54
W10X12	2.67	0.46	2	0.58
W10X15	3.32	0.5	2.49	0.63
W10X17	3.67	0.54	2.75	0.68
W10X19	4.05	0.58	3.04	0.73
W12X14	3.23	0.62	2.42	0.78
W12X16	3.64	0.64	2.73	0.8
W12X19	4.18	0.68	3.13	0.85
W12X22	4.8	0.74	3.6	0.93
W12X26	5.19	0.74	3.89	0.93
W12X30	5.96	0.76	4.47	0.95
W12X50	9.45	0.78	7.08	0.98
W14X22	4.76	0.78	3.57	0.98
W14X26	5.55	0.78	4.16	0.98
W14X34	6.92	0.78	5.19	0.98
W14X43	8.24	0.8	6.18	1
W16X31	6.68	0.8	5.01	1
W16X36	7.56	0.8	5.67	1
W16X40	8.26	0.82	6.2	1.03
W16X45	9.35	0.83	7.01	1.04
W16X50	10.39	0.83	7.8	1.04
W18X35	7.73	0.83	5.8	1.04
W18X40	8.63	0.84	6.47	1.05
W18X50	10.46	0.86	7.84	1.08
W18X60	12.53	0.86	9.4	1.08

The information provided by BIW reveals an increasing cost per pound with size for structural shapes, whereas the Kriezis method predicts a decreasing cost per pound. Further, the Kriezis method predicts considerably higher costs per pound for all structural shape sizes. Figure 4-9 presents a graphical comparison of the correct BIW information to the Kriezis method prediction for HTS shapes.

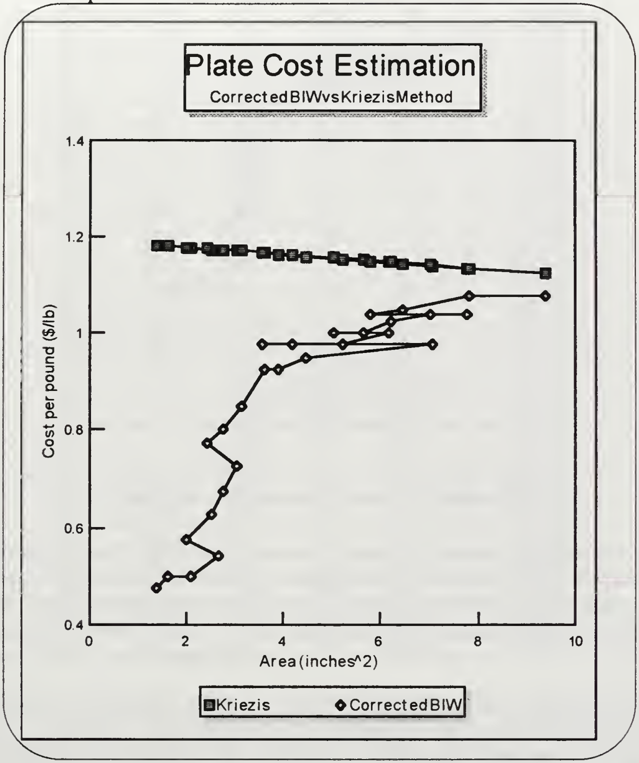

Figure 4-9 Comparison of Corrected BIW with Kriezis HTS algorithm

An empirical formula for the corrected BIW data is presented in Figure 4-10. Table 4-4 presents the data in numerical format; Figure 4-11 presents a graphical comparison of the Corrected BIW cost per pound to the empirical cost per pound.

Cost per Pound =

Tanh((AREA)^3/40-0.375)*0.375+0.6+(AREA)*0.01

Figure 4-10 Empirical Formula for Corrected BIW Information

Table 4-4 Comparison of BIW Information to Empirical Cost Estimation Factors.

Shape	Area	$/lb	Area corrected	$/lb corrected	Empirical
W6X9	1.81	0.38	1.36	0.48	0.5
W8X10	2.11	0.4	1.59	0.5	0.52
W8X13	2.8	0.4	2.1	0.5	0.57
W8X18	3.53	0.43	2.65	0.54	0.66
W10X12	2.67	0.46	2	0.58	0.56
W10X15	3.32	0.5	2.49	0.63	0.63
W10X17	3.67	0.54	2.75	0.68	0.68
W10X19	4.05	0.58	3.04	0.73	0.75
W12X14	3.23	0.62	2.42	0.78	0.62
W12X16	3.64	0.64	2.73	0.8	0.68
W12X19	4.18	0.68	3.13	0.85	0.77
W12X22	4.8	0.74	3.6	0.93	0.88
W12X26	5.19	0.74	3.89	0.93	0.94
W12X30	5.96	0.76	4.47	0.95	1
W12X50	9.45	0.78	7.08	0.98	1.05
W14X22	4.76	0.78	3.57	0.98	0.88
W14X26	5.55	0.78	4.16	0.98	0.98
W14X34	6.92	0.78	5.19	0.98	1.03
W14X43	8.24	0.8	6.18	1	1.04
W16X31	6.68	0.8	5.01	1	1.02
W16X36	7.56	0.8	5.67	1	1.03
W16X40	8.26	0.82	6.2	1.03	1.04
W16X45	9.35	0.83	7.01	1.04	1.05
W16X50	10.39	0.83	7.8	1.04	1.05
W18X35	7.73	0.83	5.8	1.04	1.03
W18X40	8.63	0.84	6.47	1.05	1.04
W18X50	10.46	0.86	7.84	1.08	1.05
W18X60	12.53	0.86	9.4	1.08	1.07

The characteristics of the empirical curve are chosen to mimic several important aspects of the "raw data". At first glance, the data suggests an empirical curve of the form " $1\text{-}\exp(A)^N$ ", where A is the cross-sectional area, and N is a power which conforms the curve to the data. However, such a curve tends to zero cost per pound at small cross-sectional areas. Using the hyperbolic tangent (TANH), the price per pound asymptotically approaches the price of plate, or roughly $0.40 per pound.

Cubing the cross-sectional area, dividing by a form factor (40) and offsetting the TANH by a small constant (0.375), are used to adjust the slope of the empirical curve through the 2 square inch through 5 square inch region of the raw data. The TANH term is adjusted to force the "lazy-s" shapes to be asymptotic at low areas to roughly $0.40 per pound and at high areas to 0.375. The constant term (0.600) adjusts the TANH vertically, to allow the TANH portion to cover the 2-4 square inch region.

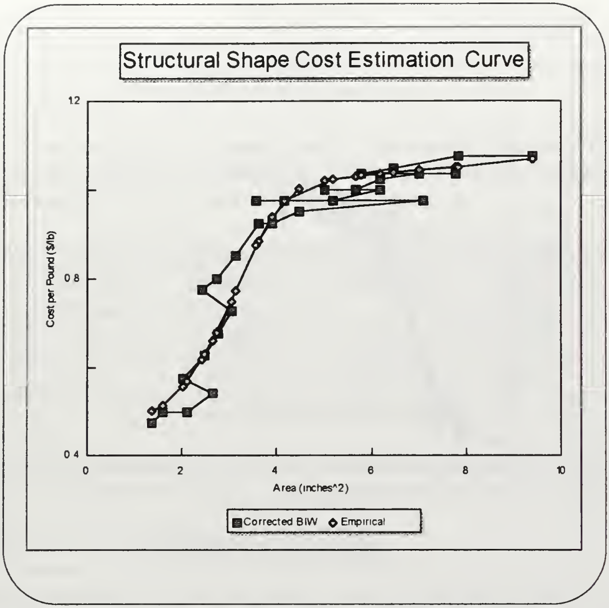

Figure 4-11 Structural Shape Cost Estimation

The linear term (A*0.01) provides a slow increase in the cost per pound for the region after which the TANH portion has reached its asymptote. The linear portion of the empirical formula is important since there are some IT structural shapes which, prior to being split to form two T's, are larger than the raw data. The raw data suggests a gentle increase in cost per pound for areas above roughly 6 or 7 square inches.

Figure 4-12 presents the empirical curve for a larger range. Note the curve is asymptotic as the area approaches zero, and increases slightly as the area exceeds 10 square inches. The reason for increasing cost with area is due to increases in cost by steel mills associated with rolling the large, heavy shapes.

4.4 Application of the Empirical Structural Shape Cost Formula

Depending on whether the cost estimate is for an I-T or and IT, the "AREA" used to apply within the empirical formula is different. For I-T shapes, the IT actual cross-sectional area of the as-used beam is the "AREA". Since the IT has no waste material, the actual cross-sectional area is first "un-corrected" for the de-flanging operation. This is accomplished by dividing the actual cross-sectional area by 1.25. Next, since the as-used cross-sectional area is actually one-half the area of the purchased beam, the area is multiplied by 2. The net adjustment to the "AREA" is a factor of 1.6 (=2/1.25). The cost of the full IT is thereby determined.

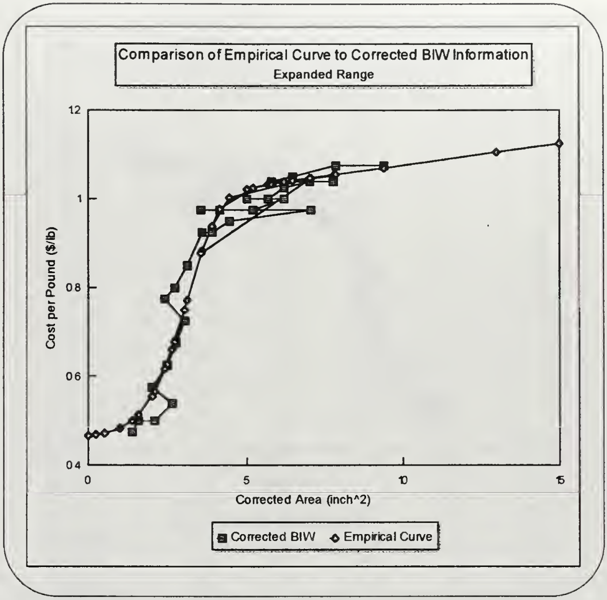

Figure 4-12 Structural Shape Cost Estimation - Expanded

After the cost of the full IT is determined, the cost is divided by two to reflect the cost of the as-used shapes. This cost scheme does not account for the cost of edge preparation of either the I-T or the IT. Both structural shape types require edge preparation at the toe of the "T" where it will be welded to the plate. However, an I-T requires more attention and man-hours preparing the edges on either side of the web from where the flange was removed. The additional cost of this edge preparation is accounted for in the "Vertical Edge Preparation" man-hour estimation of the modified spreadsheet. Further, this cost scheme does not account for the additional work content associated with the two cuts required for "I-Ts" compared to the single cut required for the "IT". See Chapter 5 for more discussion of manual cutting and edge preparation.

4.5 Summary

The BIW HTS plate information provides the most reliable and reasonable information for process-based cost estimation; and it is easy to organize for use in a spreadsheet. The information is organized in a lookup table similar to that used in the NSRP 0405 computer program.

Similarly, the BIW HTS structural shape information is the best information. The empirical curve makes application within a spreadsheet easy.

To account for the use of I-T structural shapes and the disposal of the scrap produced, its transporting and lifting costs are estimated. The man-hours to transport and lift the waste are assumed to be one half (0.5) the man-hours to transport and lift the structural members themselves. This penalizes the wastage in a conservative manner.

These material cost estimation methods applied to the midship section of DDG-51 using "I-T" and "IT" scantlings shows the difference in cost. Table 4-5 presents the material cost estimation for this analysis. Note the plate costs did not change.

Table 4-5 DDG-51 Material Costs Estimates for I-T and IT Construction

Shape Scheme	**Stiffeners & Girders**	**Frames**	**Total Material***
I-T	$13146	$11808	$67608
IT	$6295	$3793	$52742

* Plate cost estimates remain unchanged

Table 4-5 shows a cost savings of $14,866 if "I-Ts" are used instead of "ITs" for the midship module of DDG-51. Scaled to the full ship,[10] this is estimated to be a savings of $288,000.

4.6 Suggestions for Future Work

An equally important structural parameter for scantlings is the moment of inertia about the foot of the "T". Re-plotting the cost information against the moment of inertia, and producing a new empirical curve, and observing which is the dominant cost driver - the area or the moment of inertia - would be very interesting.

4.7 Conclusions

Process-based material cost estimation is possible, relatively straight-forward and directly applicable to process-based man-hour estimate methods.

[10] Applying the ratio of Structural Weight (not subject to distortion) of 2240 lton (see Chapter 6) to the module weight of 117 lton (not including pillars).

References:

Cheetam, Mark A., Bath Iron Works, FAX, Bath, ME, September, 1995.

Blomquist, Paul A., "Tee-Beam Manufacturing Analysis: Producibility of Panel Stiffening Elements", 1995 Ship Production Symposium, Seattle, WA 1995.

Brown, Alan J., un-published formulae which fit the curves published by Kriezis.

Kriezis, G. "Standardization in Ship Structural Design", SNAME Journal of Ship Production, Vol. 7, No. 1, 1991.

Chapter 5. High-Level Process Factors

In the aggregate, a process-based cost model should develop man-hour estimates which compare favorably with weight-based calculations which are based on real information. The man-hour estimates ratio'd to the weight of a particular module are, for the purposes of this thesis, termed "high-level" process factors. High-level process factors are used to validate the man-hours estimates using the modified NSRP 0405 spreadsheet.

A process-based cost estimating algorithm requires an adequate method to convert process metrics to cost estimates. If the process factors are not "correct", the cost estimate is not "correct". This section describes how the "correct" process factors are determined.

Private shipbuilders are not willing to disclose man-hour estimates. Maintaining competitive advantage as they posture for the bid process which is anticipated for LPD-17 and the new "ARSENAL" ship programs is important. This situation makes all "productivity-related" information extremely "business sensitive". Therefore, the process factors must be obtained by other means. The other means include weight-based ratios, comparisons to commercial tankers, high-level process factors published by experts, and NAVSEA Code 017 estimates.

5.1 Weight-Based Ratios

5.1.1 ASSET

ASSET's cost algorithms for one-digit Ship's Work Breakdown Structure (SWBS) Groups reflect a reasonable cost estimate for DDG-51 based on actual return costs. The structural algorithm is entirely weight based. The algorithm is presented in Figure 5-1

Inflation:

Base Year: $Y_B := 1995$ $\quad iy := 1..Y_B - 1981$

Average Inflation Rate (%) (from 1981) $R_I := 5$

$$F_I := \prod_{iy} \left(1 + \frac{R_I}{100}\right) \qquad F_I = 1.98$$

SWBS 100 costs: $\quad W_1 := 3118.05\,\text{lton}$

Structure $\quad K_{N1} := \dfrac{.55\cdot \text{Mdol}}{\text{lton}^{.772}} \qquad C_{L_1} := .03395 F_I \cdot K_{N1} \cdot (W_1)^{.772} \qquad C_{L_1} = 18.413\cdot\text{Mdol}$

Figure 5-1 Weight-Based Structural Cost Algorithm

Using a labor rate of $37.5 per hour[11] and the total SWBS Group 100 weight of 3118.05 lton, the $18.43 Mdol is converted to roughly 157 man-hours per lton. This is a top-level, weight-based man-hour factor which will be used to confirm the adequacy of the aggregate of process factors.

5.1.2 Commercial Tanker Design

To study the producibility of double hull tankers, the Ship Structures Committee developed several design alternatives for 40k deadweight ton and 90k deadweight ton tankers. The results of this study were reported in the Ship Structure Committed (SSC) Document 337 ("HULL STRUCTURAL CONCEPTS FOR IMPROVED PRODUCIBILITY"), published in 1994. This document provides several pieces of information which may be used to develop high-level process factors similar to that of the previous paragraph. Table 5-1 presents the estimates for hull-related work for the baseline ship used in the SSC-377 document. Using the information in Table 5-1, the non-design hull man-hour per lton high-level process factor is roughly 70 man-hour/lton.

Table 5-1 MARAD PD-214 Hull Work Labor Hours

Process	**Hours (X 1000)**	**% of Total**	**% of Total w/o Design**
Cut & Fabrication	110	13.6	16.6
Subassembly & Assembly	135	16.7	25
Erection	220	27.3	33.3
Production Engineering	45	5.6	6.8
Mold Loft	55	6.8	8.3
Cranes	56	6.9	8.5
Miscellaneous	40	5	6.1
Design Engineering	145	18	n/a
Total	806		
Total w/o Design	661		

[11] The PODAC study suggested a private, commercially-oriented shipyard labor rate of $23.87/hr. This rate is increased by roughly 1.5 to indicate the increased cost associated with the higher skill presumed to be required for naval construction.

The correct coefficient to use to determine the compensated gross tonnage[12] for naval vessels is a contentious issue (NSRP Panel SP-4, CAD/CAM/CIM Workshop, Feb 1996, and Storch, et al.). Storch, et al., suggest that for a DDG-51-sized naval combatant, a CGT coefficient of up to roughly 4 is appropriate. See Figure 5-2. Therefore, to "correct" the relatively complicated commercial man-hour estimates, a CGT correction coefficient of 1.5 is used. This correction adjusts the man-hour estimates from Table 5-1 to a reasonable value for naval vessels while not over-emphasizing the complexity of the naval shipbuilding. In this manner, roughly 106 man-hour per lton is a reasonable, high-level metric for steel fabrication for naval vessels. Note, this number does not include preservation or coating.

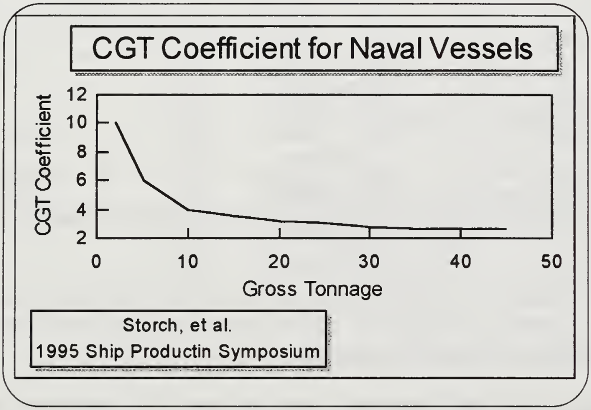

Figure 5-2 CGT Coefficients for Naval Vessels

5.1.3 MARAD PD-337 NSRP Estimate

NSRP 0239 discusses the design for a MARAD General Mobilization Vessel, PD-337. In this document, hull work labor hours are estimated. The ship, which was never built, had a GROUP 100 hull weight estimate of 9400 lton. Table 5-2 presents the weight breakdown for PD-337. In a separate figure, SSC-377 reports the PD-337 painting man-hours to be 110,000. On a per ton basis, adjusted by a GCT coefficient of 1.5, this is roughly 18 man-hour per lton for paint. Therefore after adjusting by the CGT coefficient of 1.5, the SWBS Group 110, 130 and 140 equivalent for PD-337 (hull and preservation/painting) is roughly 124 man-hours per lton.

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[12] Compensated Gross Tonnage is a measure of the difficulty of fabricating individual ship designs, and is used as a common yard stick when comparing large groups of like facilities, such as U.S. shipyards. Thye compensation takes into account the influence of ship type, complexity, and size on the work content of a particular design. For example if a shipyard has a potential throughput of 40,000 GCT per year, this is equivalent to two and one half 40,000 DWT product tankers or two 30,000 DWT container ships (Storch). It can also be used to in weigth-based cost formula.

Using the information contained in Table 5-2, the ratio of lift and transport man-hours (Cranes) to total hull man-hours[13] is roughly 8.5%. This will be another high-level factor for comparison in the following section. The ratio of cutting, welding and fabricating man-hours to total hull man-hours[14] is roughly 81.7%

Table 5-2 PD-337 Weight Breakdown Estimate (lton)

Category		**Sub-Category**		**Block**	
Structure	9,650	Hull	9,400	Bow	1,000
				Cargo	5,600
				Engine Room	1,800
				Stern	1,000
		Deckhouse	250		
Outfit	3,050	Hull	2,850		
		Deckhouse	200		
Machinery	1,830	Propulsion	950		
		Auxiliary	530		
		Electrical	350		

5.1.4 Papers Presented at Symposium

Speaking to the Ship Production Committee Panel SP-8 Concurrent Engineering Workshop, June 1995, Mr. Thomas Lamb reported that his research revealed and his expert opinion confirmed that a reasonable "current productivity" for an "average U.S. shipyard attempting to enter the commercial shipbuilding market" is 90 man-hours/CGT.

Speaking at the 1995 Ship Production Symposium, Professor Ernst Frankel of the Massachusetts Institute of Technology reported that his research has revealed that the average U.S. shipyard man-hour per CGT is 82, again for hull only work.

5.1.5 Naval Sea Systems Command Code 017 Estimates

NAVSEA 017 conducted a cost estimate for the MARAD PD-337 which was used as the baseline for the PODAC study. The SWBS Group 100 breakdown for MARAD PD-337 is presented in Table 5-3.

13 Total hull minus design engineering man-hours.

14 Total hull minus design engineering man-hours.

Table 5-3 MARAD PD-337 SWBS GROUP 100 BREAKDOWN

SWBS	Description	Weight (lton)	Man-hours	Labor $(,000)	Mat'l $(,000)	Total $(,000)	Man-hour / lton
110	Shell/structure	3,988	275,468	6,575	3,385	9,960	69.08
120	Hull Bulkhead	1,301	100,472	2,398	1,228	3,626	76
130	Hull Decks	1,346	88,855	2,121	1,089	3,210	66.03
140	Hull Platform/Flats	1,784	157,643	3,763	1,942	5,705	88.38
150	Deck House Structure	912	103,712	2,476	828	3,304	113.78
160	Special Structures	892	94,223	2,249	3,850	6,099	105.65
170	Masts, Kingposts	59	2,700	64	46	110	45.71
180	Foundations	336	43,990	1,050	216	1,226	131.05
100	Total	10,785	867,063	20,696	12,584	33,280	80.4
630	Preservation & Coverings	312	213,658	5,100	3,180	8,280	20.1*
100+630	Combined		1,080,721	25,796	15,764	41,560	102*

* SWBS 630 and "Combined" based on all Pres/Coat man-hours consumed on Group 100 items only

Adjusting the "Combined" man-hour per lton value of Table 5-3 by the CGT coefficient of 1.5 determines a naval vessel, high-level value of roughly 153 man-hours per lton.

5.2 Summary

High-level estimates for naval vessel hull man-hours per lton point to an uncorrected man-hour per lton value of roughly 100, including preservation/painting man-hours on the order of 20, for a corrected value of roughly 150. This is in general agreement with the weight-based value determined by from ASSET DDG-51 values. Table 5-4 presents a summary of the high-level factors.

Table 5-4 Summary of High-level Process Factors

Source	Category	Value (man-hr/lton)	Corrected* (man-hr/lton)
DDG-51	SWBS 100 Hull+Pres/Paint	n/a	157
MARAD PD-214	Hull+Pres/Paint	82	124
NAVSEA 017 PD-337	Hull+Pres/Paint	101	153
T. Lamb	Hull + 20 mhr for Pres/Paint	90+20= 110	165
E. Frankel	Hull + 20 mhr for Pres/Paint	82+20= 102	153
Average	**Hull+Pres/Paint**	**n/a**	**150**

*Values reported in third column corrected by 1.5 CGT Coefficient

Therefore, in the aggregate, the detailed process-based estimates should develop high-level, man-hour per lton estimates which are on the order of 150 man-hour per lton. This high-level process factor is used to validate the man-hours estimated using the modified NSRP 0405 spreadsheet.

References:

NSRP Panel SP-4, CAD/CAM/CIM Workshop, Feb 1996, June, 1995, Portland, ME.

NSRP 0239, "Design for a MARAD General Mobilization Vessel, PD-337".

Storch, Richard L., John Clark, Thomas Lamb, "Technology Survey of U. S. Shipyards - 1994", paper presented at the 1995 Ship Production Symposium, Seattle, WA.

Frankel, Ernst G., "Economics and Management of American Shipbuilding and the Potential for Commercial Competitiveness", paper presented at the 1995 Ship Production Symposium, Seattle, WA.

Chapter 6. Accounting for Weld-Induced Plate Buckling

The process of welding involves melting metal pieces which are in close proximity to each other. When the molten metal cools, a joint is formed. It is the process of heating, which occurs over a relatively short period of time, and cooling, which occurs over a relatively long period of time compared to heating, which tend to induce or allow residual stresses to develop in the metal. The residual stresses are generally thought to be the reason that distortion occurs (Masubuchi).

To adequately predict distortion at the single plate or structural shape level, many details of the individual material properties, mill process used to produce the plate, the pre-weld status of stress and strain, the thermo-elastic behavior of any coating/preservation applied, the mechanical history of the plate including shot-blasing, and details of welding technique to include the voltage and ampere regulation of the welding machine are often required. The current state of the art involves predicting the predominant post-weld distortion type, and an estimate for the extent of distortion. Modeling these variables is important and appropriate when studying panel details. Modeling the structure to determine the extent of this weld distortion is difficult and time consuming and defeats the purpose of this concept design tool.

For stiffened plates, the predominant form of post-weld distortion is buckling distortion in the direction of the stiffener. The second most predominant form of post-weld distortion is angular distortion. Figures 6-1 and 6-2 show these patterns.

Figure 6-1 Buckling Distortion

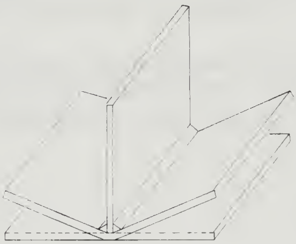

Figure 6-2 Angular Distortion

6.1 Distortion in Naval Vessels

Distortion must either be prevented through the use of strong backs or corrected by flame (or other) straightening. These corrective actions incur a cost. If this cost is non-trivial, as general agreement suggests, and if this cost is not factored into the design, the design is not cost effective. The original NSRP 0405 scheme does not account for man-hours required to remove distortion.

Welding distortion in naval vessels is of most concern in hull, deck, and deckhouse plating. The reasons for concern are many. Distortion makes the ship fabrication process longer and more expensive since fit-up and alignment are more difficult. The inherent strength of the structure in some cases is partially compromised as a result of plate eccentricity. For plate eccentricity below the waterline, hydrodynamic performance may be reduced by the presence of an uneven hull. The ship's signatures are increased as a result of plate eccentricity. And especially for superstructure plating, distortion affects the aesthetics of the ship.

6.2 Weld Distortion in DDG-51 Class Destroyers

According to analytical predictions of the Edison Welding Institute (EWI paper and Conrady paper) and based on the experience of BIW's Chief Welding Engineer reducing the welding heat input below that level required to avoid buckling distortion is not possible for plate thickness used in DDG-51. Especially for the DDG-51 program, welding distortion mitigation is very important. Some measures taken to reduce the distortion include:[15]

1. Use of flatter, specially milled (half-tolerance) plate;
2. The application of refined butt welding procedures;
3. Enhanced accuracy control programs;
4. Mechanized or automated welding.

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[15] List presented by Navy Joining Center at the National Center for Excellence in Metalworking Technologies workshop titled "Strategies to Control Distortion and Residual Stresses in Naval Shipbuilding", August 1995.

Other measures considered, but not implemented include:

1. The use (or elimination) of reduced-sized tack welds;

2. The use of reduced fillet weld size:

3. The use of pattern welding techniques[16];

4. The use of intermittent welds[17].

Despite the mathematical difficulty of predicting large-scale buckling distortion behavior, accounting for the man-hours associated with distortion mitigation is still required. The head flame straightener on BIW's day shift, with over 17 years of flame straightening experience, was particularly useful in this regard. He provided expert opinion which was useful to bound the amount of flame straightening required for the DDG-51 midship section modeled in this thesis. He reported that 16000 man-hours of flame straightening was budgeted for the first several DDG-51 Class ships built by BIW.

Conversion of this labor budget for the entire DDG-51 SWBS Group 100 to the midship section modeled in this thesis is conducted in the following manner. The weight of structure subject to distortion removal is roughly 2240 lton. See Table 6-1. Therefore, using this weight of 2240 lton, a high-level process factor for flame straightening, direct man-hours is determined to range from roughly 7.1 man-hours per lton for early BIW DDGs to 2.7 man-hours per lton for more recent DDGs.[18] Using these values, the direct labor consumed for distortion removal for the midship section modeled in this thesis ranges from roughly 370 to 140 man-hours.

Since all the parameters used to determine this value are approximations, this high-level process factor is used to bound the actual method used, which is discussed in the following section. Table 6-1 shows the method of determining the structural weight which is subject to distortion removal process.

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16 Patterned welding techniques include backstep, a series of short, non-continuous welds where gaps in the weld pattern are filled in during subsequent weld steps, wander is a similar, but less systematic series of short welds. All of which eventually result is a continuous weld.

17 Intermittent welds are welds where not all portions of the adjacent metal members are welded together, gaps remain in the finished product. This technique does not allow the residual stresses which lead to distortion to develop, yet the gaps introduce many opportunities for fracture-related failures due to the larger number of stress concentration areas and the larger number of potential crack origination sites (Masubuchi).

18 (16000 man-hours / 2240 lton) ~ 7.1 man-hours per lton. The more recent destroyers were reported to have straightening budgets of 6000 man-hours. Using this figure, the high-level process factor is ~ 2.7 man-hour per lton. The reason for this dramatic reduction are: advances in accuracy control, general learning curve increases in productivity, increased tolerance of "wavy decks" on behalf of shipyards, and learning curve increases on behalf of the flame straighteners.

Table 6-1 Determination of Structural Weight Subject to Distortion Mitigation[19]

DDG-51 SWBS Group	Category	Calculated by ASSET Structure and Weight Modules	As Reported in ASSET P&A Table	Convert by P&A Table Ratio	SWBS Groups Subject to Distortion Mitigation
110	Shell + Plate	651.6	n/a	834.52	834.52
120	Hull Bulkheads	219.2	n/a	280.73	280.73
130	Hull Decks	363.9	n/a	466.06	466.06
140	Platforms + Flats	180	n/a	230.53	230.53
150	Deckhouse	333.4	n/a	426.99	426.99
160 *	Special Structures	312.7	n/a	400.48	n/a
170 *	Mast, Kingposts	6.7	n/a	8.58	n/a
180 *	Foundations	343	n/a	439.29	n/a
190 *	Special Purpose	24.1	n/a	30.87	n/a
SWBS 100		2,434.6	3,118.05		2,238.83
* SWBS Groups not subject to distortion mitigation techniques					

The method to determine the man-hours associated with distortion mitigation, and which is used in the cost estimation spreadsheet, is a quantitative, yet not rigorous, approach. First, a method to estimate the presence of distortion is developed. Next, the man-hours to correct the distortion is estimated based on shipbuilder-provided cost information.

6.3 Distortion Cost Model

Predicting whether a particular plate will distort as a result of a certain welding operation is dependent on many variables. A robust and general method to estimate distortion which is independent of specifics concerning the plate and scantlings was sought. The literature search conducted to support this thesis failed to discover such a method.

[19] The DDG-51 data in the ASSET data bank is a "Match" of the first of class DDGs. There are many P&A Table adjustments which "correct" to values the ASSET algorithms determine to match the as-built DDG. There is an adjustment to the SWBS Group 100 weight calculated by ASSET in the DDG-51 P&A table. The ASSET weight (2434.6 lton) is subtracted completely and a fixed value of 3118.05 lton is substituted. To use this "correction" as a method of fixing ASSET for other ships of similar displacements to DDG-51, a ratio 3118.05/2434.6 used.

During the Strategies to Control Distortion and Residual Stress in Naval Shipbuilding Workshop (here after referred to as the "Distortion Workshop"), Mr. Robert Mason (Head, Accuracy Control Engineering) presented a paper entitled "End User Perspective". In this paper, he presented what proved to be information very important to this thesis.

Figure 6-3 provides Newport News Shipbuilding cost information for distortion removal.

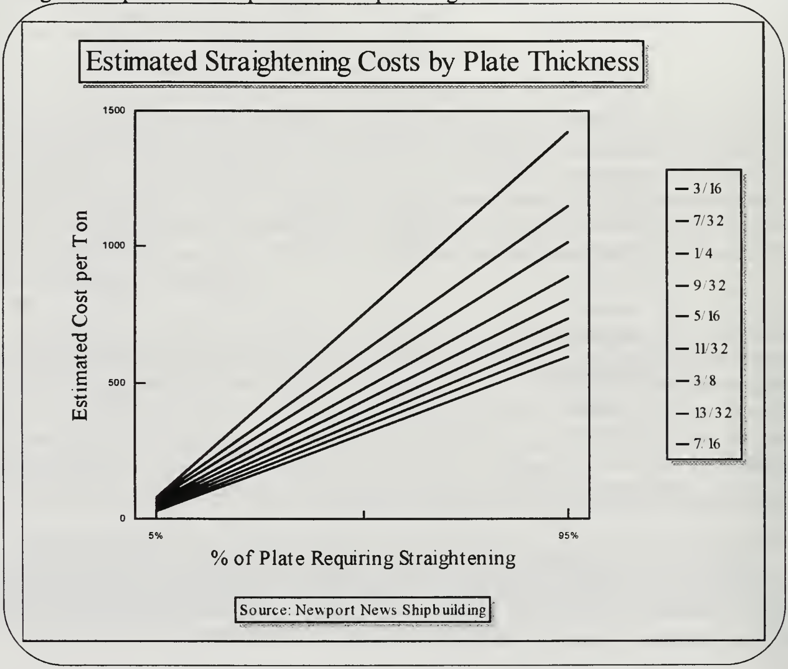

Figure 6-3 Estimated Straightening Costs by Plate Thickness

The x-axis of this figure is interpreted to mean the amount or area of a particular plate which requires straightening, although Mr. Mason does not elaborate. This is an ambiguous term describing a general extent of distortion rather than a precise area measure. The ability to predict whether any particular plate will distort as a result of welding and the extent or area distorted requires detailed modeling.

Expert opinion (see Chapter 7) is used to fashion an "extent of Distortion" curve as a function of plate thickness. Based on observations at shipyards, and expert opinion by experienced flame straighteners and welding engineers, it is generally agreed that as plate approaches thicknesses below 1/4-inch, longitudinal buckling is difficult to avoid, and virtually the entire plate (including the stiffeners) must receive flame straightening.[20]

The general approach is to estimate that as plate thickness approaches 0, buckling extent approaches 1 asymptotically, and as the plate thickness approaches one-half inch, the buckling extent approaches 0. The empirical formula is presented in Figure 6-4, where, plate thickness is "x" and "f(x)" is the extent of buckling.

$$f(x) := \exp\left(-15 \cdot x^2\right)$$

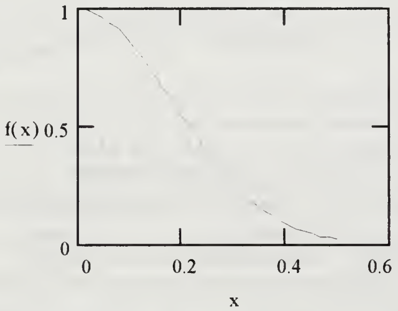

Figure 6-4 Extent of Buckling as a Function of Plate Thickness

The extent of buckling is combined with the Newport News data to produce Figure 6-5

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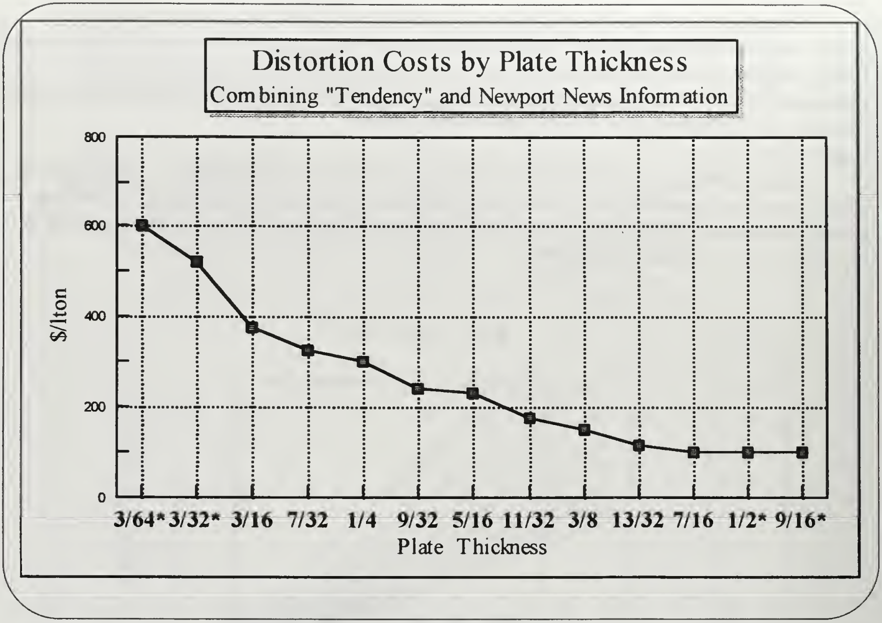
[20] Plate straightening is performed using either spot, line heating or Vee heating. Spot heating is achieved by using an oxyfuel (or equivalent) torch and heating a spot until a quarter-sized spot is just reaching red hot, then immediately cooling the spot with a water or an air/water mixture. Line heating is similar, yet a line is heated instead of a spot. Stiffener heating is similar to line heating, yet takes more heat and takes longer. VEE heating is heating a continuous line in a sinusoidal manner with increasing amplitude (Holt) (NSRP 0314). For this thesis, there is no distinction between spot, line and vee flame straightening.



* Asterisked thicknesses are extrapolations

Figure 6-5 Distortion Costs by Plate Thickness

This data is used in a look-up table within the modified spreadsheet. The cost per lton is converted to cost per inch-square foot ($\$/(inch*ft^2)$.

6.4 NAVSEA PMS 400D32 Distortion Cost Estimation

Mr. Barry Cole (Cole) states that, for DDG-51 Class ships, the labor associated with flame straightening is actually only one-tenth of the total cost associated with distortion removal. The remaining 90% of the cost is due to the inability to work near the flame, rework associated with correcting the charring caused by the flame, delays due to inability to achieve fit-up or alignment until the distortion is removed, re-priming and re-painting, distortion removal on the same plate due to residual stresses induced while flame straightening and many other reasons. The direct labor charge is $340,000, while the total impact is $3,400,000 (Cole). The $340,000 direct labor charge is converted to direct man-hours; this man-hour value is used to determine the man-hours per lton for the midship section of DDG-51. See Table 6-2. Converted to man-hours per lton, the Cole estimate is 4 man-hours per ton. This man-hour per lton is used for comparison to other distortion man-hour estimates.

Table 6-2 Determination of Direct Straightening Hours - Cole Estimate

Parameter	Value
Direct Straightening $	340,000
Assumed Labor Rate $/mn-hr	37.5
Direct Man-hours Entire Ship	9,066.67
Ratio Weights (Module/ SWBS 100*)	58.84 / 2240
Direct Man-hours for Module	238.14
man-hours per lton	4

* SWBS 100 Weight adjusted as discussed in paragraph 6.2

Assuming that 25% of the total impact reported by Cole is associated with support labor hours, the ratio of total distortion-related disruption labor hours to direct labor hours is 6.5[21]. Therefore, the direct labor hours determined using the methods of paragraph 6.3 are multiplied by 6.5 to account for the disruption caused by flame straightening.

Table 6-3 presents the comparison of distortion related man-hours for a DDG-51 midship section.

Table 6-3 DDG-51 Midship Section Distortion Man-hour Estimates

DDG-51 Midship Section Model		**Direct man-hours**	**Total man-hours (Increase Factor = 6.5)***
Weight-based	7.1 man-hour/lton	418	2,717
	2.7 man-hour/lton	159	1,033.5
Cole Estimate	4.0 man-hour/lton	238	2380*
Process-based	"extent" method	131	851.5
DDG-51 Module Weight = 58.84 lton			

*Cole Estimate Increase Factor = 10.

21 ((\$3.4Mdol * 0.75)-\$3.4Kdol)/\$3.4Kdol ~ 6.5

Table 6-4 presents the results of Table 6-3 scaled to the entire ship using a "distortable" SWBS Group weight of 2240 lton (see paragraph 6.2).

Table 6-4 DDG-51 Total Distortion-Related Man-hour Estimates[22]

DDG-51 Entire Ship		Direct man-hours	Total man-hours *	Total Cost***
Weight-based	7.1 man-hour/lton	15,913	129,293	$4,848,488
	2.7 man-hour/lton	6,053	49,181	$1,844,288
Cole Estimate		9,067	90667**	$3,400,000
Process-based	"tendency" method	4,987	40,519	$1,519,477

*Increase factor = 8.125, To account labor hours, a correction of 1.25 is made for support (6.5*1.25=8.125). **Cole Estimate Increase Factor remains = 10. ***Using $37.5/man-hour

6.5 Summary

The NSRP 0405 spreadsheet is modified to account for man-hours devoted to distortion removal. The distortion removal cost per lton is determined using the look-up table (units are: $/(inch-ft^2). This parameter is converted to man-hours using $37.5 per man-hour. The resulting direct labor hours are multiplied by 6.5 to account for delays and re-work associated with the flame straightening.

The Process-based distortion cost estimate conservatively under-estimates the cost of flame straightening compared to the other methods. The information used to develop the process-based method is based on several different reliable sources and is used in this thesis.

[22] The method to determine the man-hours is: multiply the direct distortion man-hour for the module by the ratio of total Group 100 weight susceptible to distortion (2240 lton) divided by the module structural shape and plate weight (58.84 lton).

References:

Cole, Barry, "Cost of Non-Fairness of Thin Plate Steel Decks and Bulkheads During Construction of New Ships for the U.S. Navy", NJC/NCEMT Workshop: Strategies to Control Distortion and Residual Stress in Naval Shipbuilding, Annapolis, MD, August 1995.

Conrady, Chris, and Randy Hull, "Control of Distortion in This Ship Panels", Edison Welding Institute, paper presented at the SNAME Ship Production Symposium, 1996, San Diego, CA.

Edison Welding Institute and Navy Joining Center Paper number TDL #93-04, presented at Navy Joining Center at the National Center for Excellence in Metalworking Technologies workshop titled "Strategies to Control Distortion and Residual Stresses in Naval Shipbuilding", August 1995.

Holt, R., "How to Control and Correct Warping," Welding Design and Fabrication, June 1977.

Masubuchi, Koichi, Analysis of Welded Structures, Pergamon Press, 1984.

National Shipbuilding Research Program Document 0314, Ron Besselievre and Lee Norton, Ingalls Shipbuilding, September 1990.

Chapter 7. Refinements to Process-Based Estimate for Ship Construction Cost

As outlined in Chapter 4, the computer program developed by NSRP 0405 provides a method to estimate structural installation costs on a per piece basis. However, there are several aspects of this program which need revision or enhancement to effectively evaluate the producibility and cost of a full ship. The aspects of the NSRP 0405 which are deficient will be discussed in detail in this chapter. The deficiencies include:

1. The layout of the computer input range of the computer program precludes estimating more than one structural member, shape or plate at a time.

2. Some process factors require modification.

3. The structural steel computer program does not include structural pillars or columns.

4. The layout is not organized to make data exchange between structural analysis computer routines quick and free from transcription errors.

5. The overall scheme is not sensitive to producibility enhancements.

6. The overall scheme does not include the effects of distortion mitigation and removal. (Discussed in Chapter 7).

7. The overall scheme does not include a method to address the potential for labor reduction which may result from designs which require few types or sizes of structural plates.

In the remainder of this chapter, these deficiencies are addressed individually, and modifications to the original computer program to enhance its capability and effectiveness are described.

A "Basic Outline of Method" is found in Appendix 3. A description of how to obtain ASSET structural shape information is found in Appendix 4. A description of how "Ranges" are used in the modified spreadsheet is found in Appendix 5. A detailed description of each cell in the main portion of the modified spreadsheet is found in Appendix 6. A description of ;pillar calculations is found in Appendix 7. A description of how welding edges are determined is found in Appendix 8.[23] Appendix 12 presents a copy of the main portions of the FSC spreadsheet. Appendix 13 presents the FSC spreadsheet in "TEXT" format to allow reference by future users.

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23 Appendix 9, 10, 11refers to information related to Chapter 8.

7.1 Expert Opinion

To validate the methods used to address the deficiencies mentioned in the previous paragraph, expert opinion was obtained. The experts used to form the expert opinion include individuals within the public and private sector. They represent hundreds of man-years of experience in shipbuilding. Individuals contributing to the formulation of expert opinion concerning the shipbuilding process factors are listed in Table 7-1. A copy of a sample letter soliciting expert opinion is included in Appendix 10.

7.2 Layout Revision - Multiple Members

As depicted in Table 4.1, the original program layout produced a cost estimate for only a single structural member's installation. The spreadsheet layout is revised to accommodate cost estimation of an entire midship section simultaneously.

The midship section is used by virtually all strength analysis methods to size the primary structure of the ship, and to validate the design against the various loads to which the ship will be subjected. See Chapter 3 for more discussion of structural analysis.

Further, the midship section is representative of the remainder of the ship. The materials and the choice of structural shape and plate sizes used in the midship section are used as a guide for scantlings throughout the ship except for the bow and stern which are uniquely designed.[24]

As developed in Chapter 1, the structural design is only one facet of the overall ship design. There must be some means of evaluating the impact of structural design choices on the overall performance and characteristics of the ship. A reasonable approach to evaluating this impact is to integrate structural design with a design synthesis tool. ASSET is the concept design synthesis tool used by U.S. Navy ship designers. It is a logical choice for such integration. Additionally, ASSET uses the midship section for structural strength analysis, as well as weight, space and volume estimation. ASSET produces entire ship estimates for strength and weight using a parametric approach, with the midship section as the reference. Other tools used to address the performance of each design alternative include the FASTSHIP hull geometry modeling computer program, the NAVSEA HULL FORM DESIGN SYSTEM, to name a few.

The flexibility of the approach described within this thesis is that the process-based model can be used for as much of the ship as is necessary to make the producibility decisions and to determine the impact of these decisions on the performance of the design alternative. The remainder of the structural estimate is weight-based.

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[24] Through application of parametrics, parameters and characteristics of sections forward and astern of the midship may be modeled. The bow and stern are not easily modeled using the midship section as the basis. These sections of the ship have significantly more curvature and more rigid structure, making the use of parametrics difficult. The details of these sections may be modeled individually once the ship's form is well described, and the modified spreadsheet used to produce a cost estimate with high fidelity. Cost estimates near the extremities of the ship are not addressed in this thesis.

Table 7-1 Individuals Included in Expert Opinion

Public Agency Related:	CAPT. A. Brown: USN	Prof. Naval Arch. & Marine Eng. MIT
	CAPT. G. Kraine: USCG (Ret.)	Now in Private Practice
	LCDR M. Welsh, USN	Ass. Prof. Naval Arch. & Marine Eng. MIT
	CAPT. J. Wilkins: USN (Ret.)	Now in Private Practice
	B. Cole	Deputy Prog. Man, AEGIS PMS 400D32
Academia:	Professor K. Masubuchi	Kawasaki Professor of Welding and Marine Materials MIT
	Professor H. Marcus	NAVSEA Professor of Ship Acquisition MIT
	P. Blomquist	Research Scientist Penn. St, APL formerly w/ BIW
	R. Moore	Adjunct Associate Professor U.Michigan
	H. Bunch	Professor Emeritus U. Michigan
	P. Cahill	Research Assistant U. Michigan
Symposia:	SNAME Annual Meeting	1994
	Ship Production Symposium	1995
	Commercial Shipbuilding in USA	1995
	Concurrent Engineering Workshop	1995
	Strategies to Control Distortion and Residual Stresses in Naval Shipbuilding	1995
	Ship Production Symposium	1996
	CAD/CAM CIM Workshop	1996
	Dealing w/ Distortion and Residual Stresses in SC-21	1996
Bath Iron Works:	D. Forrest	Chief Welding Engineer
	R. Hoffman	Manager, Commercial Shipbuilding
	P. Friedman	Manager, CAD/CAM/CIM
	S. Lardie	Manager, Project Planning, Production Planning and Control
	individual craftsmen and shop floor personnel	Harding Plant and Waterfront Facilities*
Newport New Shipbuilding:	R. Mason	Head Accuracy Control
	S. Sawhill	Chief Welding Engineer
Ingalls Shipbuilding:	R. McClellan	Welding Engineer
	K. Perry	Director, Cost Engineering

* Many craftsmen and shop floor individuals were consulted during several tours of the Hardings Plant and BIW Waterfront Fabrication Facilities. Extensive observations and comments were obtained during these tours concerning de-flanging operations and weld distortion removal and mitigation techniques.

7.2.1 Modified Layout Organization

To produce a structural strength analysis and cost estimation, the location and size of the individual structural members are required. Since the synthesis tool, ASSET, is where the ship designs begins, output from ASSET is the logical place from which to obtain this data.

One of the individual modules of ASSET is the HULL STRUCTURE Module; see Appendix 11. The output from this module provides geometric information and midship section scantlings.[25] The general order found in the ASSET HULL STRUCTURE Module output is the order to which the spreadsheet has been arranged.

The information needed for structural analysis and cost estimation is for the hull shell and supports (SWBS Group 110), hull decks (SWBS Group 130) and platforms and flats (SWBS Group 140). ASSET's HULL STRUCTURE Module output is organized into fifteen different reports. The ASSET reports for these SWBS Groups are those for the weatherdeck, side shell, bottom shell, inner bottom, internal decks, floors and girders.[26]

An internal ASSET algorithm further divides the weatherdeck, side shell, bottom shell, inner bottom and internal decks into segments. There are roughly three to five unique segments (due to symmetry, six to ten for the entire midship section) for each of these structural members. The girders, frames, longitudinals, floor and plates are represented separately and individually among the reports.

The spreadsheet was rearranged to mimic the ASSET report organization.

7.2.2 Modified Layout Description

The modified spreadsheet is organized to estimate the installation cost of all primary structures for the weatherdeck, side shell, bottom shell, inner bottom, internal decks, floors and girders. There are individual rows to estimate the cost for each structural segment (e.g. 3 segments of weatherdeck, four segments of side shell, and so forth). The general arrangement is from centerline outboard, high to low. Notable exceptions are the bottom shell and inner bottom which are numbered from outboard to inboard. Further details of the modified spreadsheet are found in Appendix 6.

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[25] ASSET uses symmetry about the centerline, therefore only one half of the ship is presented in the output.

[26] Reports Number 3 (Weather Deck), 4 (Side Shell), 5 (Bottom Shell), 6 (Inner Bottom), 7 (Internal Decks), 10 (Girder Properties, Strength, Stresses and Factor of Safety), 13 (Side and Bottom Frames) and 14 (Deck Beams).

7.3 Modification of Process Factors

The two principal authors of the NSRP 0405 document, Dr. James Wilkins and CAPT. Gilbert Kraine (USCG, Ret.), were queried about how the process factors were developed (Wilkins) ,(Kraine). Dr. Wilkins provided a copy of some of the material used to produce the process factors published in NSRP 0405. Both Dr. Wilkins and CAPT Kraine confirmed that the information they used to prepare the fabrication process factors were largely based on ship repair figures and the professional and shipyard experience of all the authors involved.[27] Additionally, both Dr. Wilkins and CAPT Kraine reported that the process factors for material receipt and preparation, shaping (rolling and line heating), transport, lifting, blasting and coating were based on the combined shipyard and professional experience of all the authors and assistants who produced NSRP 0405.

Using the original NSRP 0405 process factors, a DDG-51 midship section requires 15074 direct labor hours to fabricate. This is roughly 350 man-hour per lton.[28] In order to achieve a high-level process factor similar to that developed in Chapter 7, roughly 150 man-hours per lton, modifications to the process factors are required. These factors are addressed in the following paragraphs.

7.3.1 Material Receipt and Preparation

In 1994, the original NSRP 0405 spreadsheet was used to conduct an analysis of hull structural concepts for improved producibility for 40K and 94K deadweight double hull tankers by the Ship Structure Committee (SSC). This analysis is documented as SSC-377, produced by M. Rosenblatt & Son, Inc. for the U. S. Department of Commerce. The fact that the spreadsheet was used by this committee testifies to the credibility of the technique and the general acceptability of the individual process factors. The first factor identified for adjustment was for Material Receipt and Preparation. The authors of the SSC-377 document reported that the 0.1 man-hour per piece for material receipt and preparation was an order of magnitude large. A process factor of 0.01 man-hour per lton was used in SSC-377 and is used in this thesis.

7.3.2 Shaping and Forming

Expert opinion was solicited concerning shaping and forming. It was generally agreed that shaping and forming are highly dependent on the complexity of the final shape desired, the skill of the craftsmen, the material and other factors. However, it was also agreed that the original NSRP 0405 process factors are too high. Based on this expert opinion, the original factors for line heating are reduced by an order of magnitude to rectify and balance the shaping man-hours compared to fabrication labor content.

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[27] The methods and mechanics which were used to translate the Engineered Method and Standards from the former Philadelphia Naval Shipyard (PNS) were not provided by Dr. Wilkins, or CAPT Kraine, nor were they described in NSRP 0405. However, there is general agreement between the Engineered Method and Standards from the former Philadelphia Naval Shipyard and the process factors found in NSRP 0405.

[28] Support labor hours are assumed to be roughly 25% of direct labor hours.

The roll process factors are also reduced by roughly an order of magnitude. However, it was agreed that more discrimination is required as the structural shape thickness increases. The revised roll factors are listed in Table 7-2.

Table 7-2 Comparison of Shaping Process Factors
(per piece)

Thickness	Original Factor Rolling	Revised Factor Rolling	Original Factor Line Heating	Revised Factor Line Heating
0.13	n/a	0.08	10	1
0.25	1	0.1	10	1
0.38	1.2	0.12	10	1
0.5	1.2	0.13	10	1
0.75	1.2	0.13	10	1
1	1.2	0.14	10	1

7.3.3 Movement of Structural Members

Similarly, based on this expert opinion, the transport and lifting process factors are reduced by an order of magnitude. This is largely due to the original NSRP reference unit being "assembly", a vague term, whereas in this thesis, the reference unit is per piece. The transport and lift process factors used in this thesis are 0.5 man-hour per piece.

7.3.4 Blasting and Coating

Current industry practice is to use 0.1 man-hour per square foot, counting only "one side of paintable surface". However, what "one side paintable surface" means in practice is considered to be "proprietary information". To avoid confusion and to clarify what could be a vague description, the paintable surface used in this thesis is the total surface area. As developed in Chapter 5, a reasonable high-level process factor for preservation and painting is roughly 20 man-hours per lton. The original NSRP 0405 process factor results in a high-level process factor of roughly 60 man-hours per lton, using a 0.1 man-hours per square foot. To bring the high-level factor closer to that developed in Chapter 5, the original NSRP 0405 factor is reduced by a factor of 3. The blasting and coating process factors used in this thesis are 0.033 man-hour per square foot (counting both sides).[29]

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[29] It is interesting to note that the choice of 0.033 man-hours per square foot is roughly 10 times larger than the value suggested by the PODAC study. This suggests actual blasting and coating activities only consume 10% of the total Preservation/Painting man-hours, and the remainder of the time is used for set-up, maintenance and the like.

7.3.5 Edge Preparation

De-flanging "I-Ts" creates two surfaces per beam which require post-de-flanging surface repair/preparation, whereas splitting "ITs", especially if performed at the mill, results in only one surface per beam. See Figure 7-1. To account for this additional edge preparation, adjustments to the algorithm used to determine the vertical edge preparation man-hours are required.

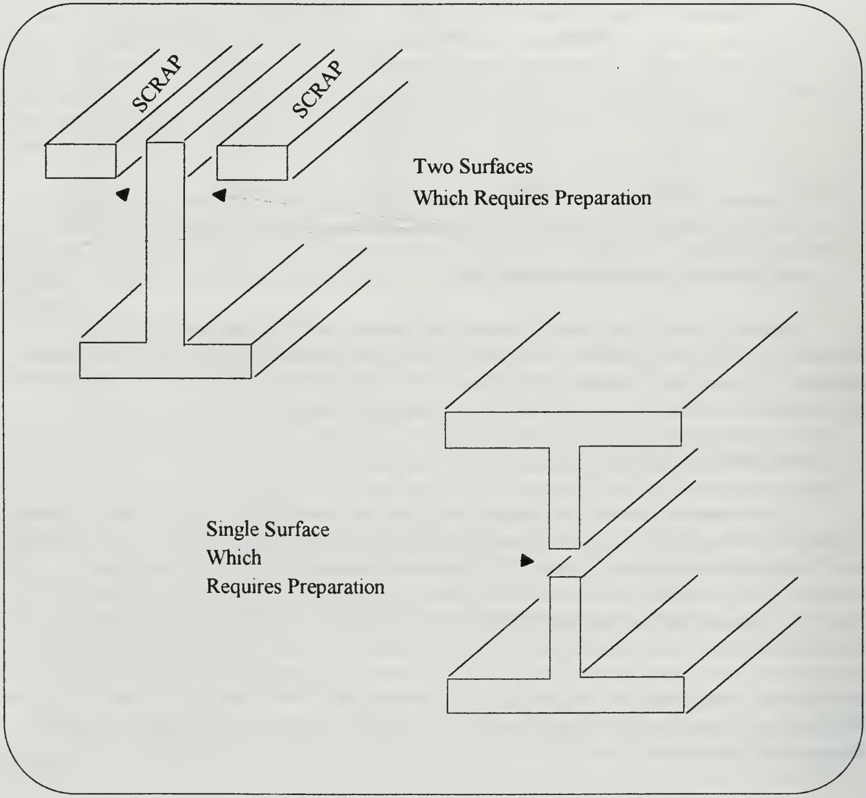

Figure 7-1 Structural Shape Edges

For "I-T" beams, the vertical edge preparation is considered to be both sides of the full-height web. This is because the edges exposed as a result of cutting off the flanges must be dressed prior to transporting to storage or to the panel line. The length of stiffener which requires "edge dressing" is considered to be one-tenth that of edge preparation prior to landing a stiffener for welding. This reduction by a factor of ten is intended to penalize the use of "I-T". Expert opinion suggests the factor of ten reduction is required since the post-de-flanging surface repair/preparation is not as labor intensive as that required immediately prior to welding.

Reducing the edge preparation length by one-tenth may be overly conservative. Use of a larger factor would only serve to further make the case for the use of "ITs" instead of "I-Ts". Additionally, for "I/Ts", the manual cut length is twice the structural member length, whereas for "ITs" the manual length is only the length of the structural member.

Once at the panel line, both "IT" and "I-T" stiffeners require edge preparation; however, at the panel line, edge preparation is generally considered to be horizontal, whereas edge dressing of the "I-T" is considered vertical due to the position and orientation observed in practice at BIW and National Steel and Shipbuilding Company (NASSCO).

7.4 Inclusion of Structural Pillars

A specific structural detail which should be included in this process-based cost estimate is pillar fabrication. Pillars are large sized pipes or tubes which are used to support decks and to "tie" the structure together other than at transverse bulkheads. See Figure 7-2. Pillars provide only axial strength and do not provide resistance to bending. This is why they are important during Main or Weatherdeck Wetness conditions and during damage analysis when it is assumed that the Damage Control Deck[30] is flooded.

The pillars described in the Detail Design of the DDG-51 were Standard Weight Pipe with outside diameter 10.75 inches and wall thickness 0.365 inches. These values were used as the reference size and weight for comparison purposes. The sizes for other standard weight pipes were determined using the Manual of STEEL CONSTRUCTION, Allowable Stress Design, by the American Institute of Steel Construction, Inc.

The NSRP 0405 structural steel computer program does not include structural pillars or columns. However, NSRP 0405 does provide a separate computer program to estimate the installation cost of piping.

The NSRP 0405 Carbon Steel (P1) piping installation spreadsheet is included within the modified NSRP 0405 spreadsheet. The revised layout is organized similarly to that described in paragraph 7.1. There is a row for each pillar. Those activities not associated with installing pillars in structures (butt welding, hydrostatic testing, insulation and the like) are not included in the modified spreadsheet.

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[30] The Damage Control Deck is usually defined as the 1st deck below the Weatherdeck which is continuous. This deck is often the only deck on which personnel may pass from one compartment to another. During periods where damage potential is elevated, the ship is "sealed" and its full integrity established. Full integrity implies that water entering above the Damage Control Deck remains on this deck and, therefore, the deck must be able to support the additional weight.

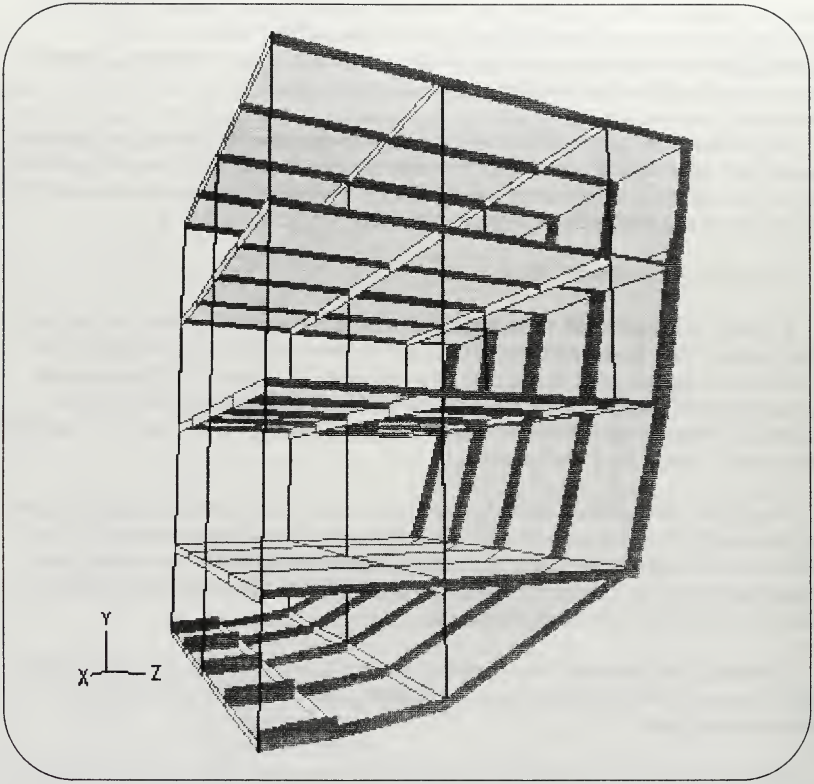

Figure 7-2 The Use of Pillars in a Structural Design

7.5 Interface with MAESTRO

The layout of the original NSRP 0405 spreadsheet is not organized to make data exchange between structural analysis computer routines quick and free from transcription errors. The topology and panel units for the midship section are determined and arranged within the spreadsheet to be consistent with MAESTRO "data" file requirements.

Specifically, the following items need to be extracted from the spreadsheet and entered in the MAESTRO "data" file:

1. The panel endpoint locations. These are determined by the node locations which are calculated by ASSET or which are user-defined.

2. The panel scantlings. This information is required to be arranged in a particular format. The modified spreadsheet is so arranged.

3. The girder scantlings. This information is required to be arranged in a particular format. The modified spreadsheet is so arranged.

4. Frame scantlings. This information is required to be arranged in a particular format. The modified spreadsheet is so arranged.

If the scantlings exported to the MAESTRO "data" file do not result in satisfactory or adequate structural performance, adjustments are required. The adjustments generally fall into one of the following categories[31]:

1. Changes in the number of stiffeners, girders, frames.

2. Changes in the individual structural shape sizes.

3. Changes in the number of pillars.

4. Changes in the individual pillar size.

After adjusting these factors as required to obtain a satisfactory structure, the final number and size of the scantlings are exported from MAESTRO and into the modified spreadsheet. Again, the revised layout of the spreadsheet makes this export process easy and relatively free from transcription errors.

7.6 Producibility Adjustments to Process Factors

The NSRP 0405 scheme is not sensitive to producibility enhancements inherent in the design. In particular, it could not discern between a design based on using only one plate material of a single thickness stiffened with only a single size stiffener (the most producible case) and a design based on multiple materials all of various thicknesses, stiffened by many differently sized structural shapes (the case of DDG-51).

Since a rigorous approach to quantifying the savings associated with reducing the number of unique structural shape sizes is not feasible, an empirical approach is taken. For the purposes of this thesis, the number of unique materials, plate thickness and stiffener sizes used for the DDG-51 Detail Design is used as a reference. There are at least 30 unique structural materials and/or sizes used. Expert opinion was obtained in order to quantify producibility savings. Individual algorithms, based on this expert opinion, are developed for the following process factors and are discussed in subsequent paragraphs:

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[31] An optimization routine can be activated within MAESTRO to vary these, and other factors to meet user-defined criteria (such as keeping the flange breadth to 0.7 times the web height) in order to produce a satisfactory structure. See the MAESTRO User Manual for further details.

- Material Receipt and Preparation;
- Marking;
- Storing;
- Transporting;
- Lifting;
- Blasting;
- Coating.

The general method is to determine the ratio of the number of different plate materials/thicknesses and structural shape sizes to 30 (DDG-51). For this thesis, this ratio is termed "producibility factor" (PF). Therefore, a design alternative which has a total of 30 unique structural shape sizes/materials receives a PF of unity.

The PF is used as a weight for adjusting the process factors. Further, there is a dependency for each individual process factor on the number of unique structural shape sizes/materials. A survey of expert opinion obtained consensus on the use of a PF and the weighting relationships used in the dependency algorithms. Table 7-3 presents the PF dependency algorithms.

Table 7-3 Producibility Factor Dependency Algorithms

Process	**Dependency**	**Constant**	**Algorithm**
Highly Dependent	0.65*PF	0.35	0.35+0.65*PF
Strongly Dependent	0.5*PF	0.5	0.5+0.5*PF
Moderately Dependent	0.35*PF	0.65	0.65+0.35*PF
Slightly Dependent	0.15*PF	0.85	0.85+0.15*PF

Concerning Highly Dependent Processes

Expert opinion suggests the Material Receipt and Preparation process is highly dependent on PF. The fewer uniquely sized structural members which require receipt, preparation and handling, the more streamlined the process. The man-hours associated with receipt and preparation are more dependent on the number of uniquely sized structural members than on the nature of the process itself. Fewer different sizes means deliveries are received in bulk, this reduces time and helps to avoid accounting and ordering/delivery errors. Perhaps the biggest contribution to labor reduction is the fact that with fewer different sizes, tracking individual parts and insuring the pedigree of individual parts is made easier.

Concerning Strongly Dependent Processes

Expert opinion suggests the Storage process is strongly dependent on the PF. As with material receipt and preparation, storage of structural members is highly dependent on the number of uniquely sized structural members. Fewer different sizes requires fewer different storage jig designs. Further, fewer different layout locations are required so layout space is potentially reduced, perhaps even opening the possibility for blue sky layout spaces to be covered. This tends to enhance productivity and can reduce environmental attack of the stored members.

Concerning Moderately Dependent Processes

Expert opinion suggests the Transportation process is moderately dependent on the PF. Transportation labor hours are reduced since access in the storage facility is enhanced. Since there are fewer different sizes, more bulk lifts are possible and the opportunity for error is reduced. Tracking individual parts is easier. However, the interim products which are fabricated still require transportation; therefore, only slight modification to the original process factors is made.

Concerning Slightly Dependent Processes

Expert opinion suggests the Marking, Lifting, Blasting and Coating processes are slightly dependent on the PF. Labor hours for marking, lifting, blasting and coating are only somewhat reduced by having fewer structural member sizes. These categories remain predominantly influenced as suggested by the original process factors.

The revised process factors to are presented in Table 7-4.

Table 7-4 Comparison of Process Factors

Category	NSRP Factor (man-hour/unit)	Revised Factor (man-hour/unit)
Material Receipt & Prep	0.1 / ft^2	0.01*(0.35+0.65*PF) / ft^2
Marking	0.1 / piece	0.1*(0.85+0.15*PF) / piece
Storing	0.1 / piece	0.1*(0.5+0.5*PF) / piece
Transportation	5.0 / assembly	0.5*(0.65+0.35*PF) / piece
Lifting	5.0 / assembly	0.5*(0.85+0.15*PF) / piece
Blasting	0.1 / ft^2	0.033*(0.85+0.15*PF) / ft^2
Coating	0.1 / ft^2	0.033*(0.85+0.15*PF) / ft^2

7.7 Summary

Based on the information presented in chapter 5, a relatively high confidence is placed on the cost estimate. The ratio of material cost to total labor cost using the original NSRP 0405 process factors is roughly 10%. Bunch, et al. assert that this ratio is 40/60. Based on expert opinion, the expected value for this ratio is roughly 0.20-0.5 (25% - 50%). The material cost to labor ratio is roughly 19%. While the high-level factor remains a little higher than the target, the method of reducing the process factors is sound and without further evidence or documentation, other adjustments to the process factors are not prudent. After modifying the NSRP 0405 process factors, the high-level process factor is roughly 176 man-hours per lton (without the distortion man-hours).

With these revisions to the original NSRP 0405 spreadsheet, a cost estimate for multiple structural members may be determined. The original spreadsheet is revised to accommodate importing offset and structural shape information from the U.S. Navy's ship synthesis tool, ASSET. It is also revised to accommodate the manual exchange of information with a rationally-based finite element computer program, MAESTRO. Structural pillars, in addition to plates, strakes and structural shapes are now part of the cost estimate methodology. The scheme is sensitive to some producibility enhancements that may be considered at the concept design stage. Further, the scheme is sensitive to the impact that distortion removal has on structural cost estimates.

Table 7-5 compares the original and revised man-hour breakdown.

Table 7-5 Man-hour Estimate for DDG-51 Comparison to Original NSRP 0405

Process	Original	Thesis Results	Relation to Original
Matl Rec&Prep	781	78	/10
Auto Flame Cut	56	56	
Manl Flame Cut	77	151	
Edge Prep Flat	250	250	
Edge Prep Vert	3	19	
Edge Prep Ovhd	0	0	
Shape - Roll	248	25	~ /10
Shape - Line Ht	910	91	/10
Fit-Up &Ass'bly	2,107	2,107	
Distortion	852	852	
Auto - Fillet	95	95	
Auto -Butt	461	461	
Man - Fillet D*	770	770	
Man - Butt D*	1,373	1,373	
Man - Butt V*	442	442	
Man - Butt O*	0	0	
Marking	36	36	
Store	39	39	
Transport	1,940	194	/10
Lift	1,940	194	/10
Blast	1,562	521	/3
Coating	1,562	521	/3
Direct Labor	15,504	8,185	
Total Labor	19,380	10,231	
manhr/lton=	328	176	
manhr/lton**=	316	158	
(C+W+F)/Total Labor =	0.45	0.74	
Cutting+Welding +Fabrication=	6,793	5,750	
Scantling Cost	67,608	67,608	
Scantling $ / Labor $	0.1	0.19	

* "D" - Downhand; "V" - Vertical; "O" - Overhead

** Values exclude man-hour estimates associated with correcting distortion

References:

Blomquist, Paul A., "Tee-Beam Manufacturing Analysis: Producibility of Panel Stiffening Elements," 1995 Ship Production Symposium, Seattle, WA 1995.

<u>Manual of STEEL CONSTRUCTION, Allowable Stress Design</u>, by the American Institute of Steel Construction, Inc., Chicago, IL

National Shipbuilding Research Program, NSRP 0235, "Labor Standards Application Program, Blast and Paint Shops," Peterson Builders, Inc. Sturgeon Bay, WI, December 1984.

Chapter 8. Application of Process-Based Cost Estimate Tool

The methods developed in this thesis were applied to an academic exercise in new construction, concept-level ship design; the Future Surface Combatant (FSC). FSC was constrained to have a full load displacement of less than 7000 lton. Based on trade-off study results, the design team choose fuel cells as the prime mover. Due to the low over-head height requirement of the fuel cells, traditional multi-level machinery spaces were avoided; therefore, only continuous decks within the hull were required.

The process-based cost estimate tool developed in this thesis was applied to analyze the structural integrity, and estimate the cost of the midship section of FSC using thick plate and light structural shapes. This design alternative is referred to as the "producible FSC". To compare the cost, and performance of the producible FSC to a thin plate, heavy scantling design, a "traditional" design alternative was developed and analyzed. The comparison of these design alternatives follows.

8.1 Development of FSC Midship Section

The structural design and analysis for FSC focuses on the midship section. A traditional longitudinally stiffened, transverse frame scheme is used. Girders are supported by pillars, on every other frame. High Strength Steel is used for all plates. "T-beams" are used for stiffeners, girders, and frames. An average stiffener spacing of 28 inches is modeled in ASSET. Frame spacing is 8-feet.

Conditions of vertical bending (hogging and sagging), vertical shear, point loads representing an estimate for the Full Load weight distribution (except SWBS Group 110, 130 and 140), green water on the weatherdeck and flooding load on the DC deck were modeled in MAESTRO, and structural shapes designed to satisfy all limit states. The "data" file for FSC is presented in Appendix 9a, along with the methodology of estimating vertical bending moment and Full Load weight distribution.

The structural model produced by ASSET was used to prepare the structural offsets.

Brackets was modeled connecting the weatherdeck to the side shell, and the first inner deck to the side shell. The brackets modeled for the ASSET and Revised ASSET designs (discussed below) are based on the DDG-51 Detail Design. The brackets modeled for the Producible Design are consistent with the choices for plates and structural shape sizes which follow.

FSC has 128 feet, roughly 30% of the ships length, of parallel middle body. There are obvious producibility benefits associated with the fabrication of identical sections, which the use of parallel middle body allows.

To quantify the cost savings associated with the fabrication of identical modules, a learning curve is applied. For each identical and repeated module, beginning with the second, the cost is reduced by a learning curve factor. For this thesis, a conservative learning curve factor of 0.97 is used. If the first module is estimated to cost $100, the second module will be estimated to cost $100*0.97, the third module will be estimated to cost $100*0.97*0.97, and so forth.

Where practical, the length of the parallel middle body is an integer multiple of the module length. To remain conservative, for parallel middle body lengths which are not integer multiple of the module length, the ratio of parallel middle body to module is rounded down to the nearest integer. So for a parallel middle body length of 112 feet and a module length of 40 feet, the ratio 2.8:1 (112/40) is rounded down to 2. This would mean that the learning curve factor would be used only once.

Figure 8-1 presents the learning curve for total man-hours consumed per New-Build for the TRIDENT Class Submarine as reported by Electric Boat.

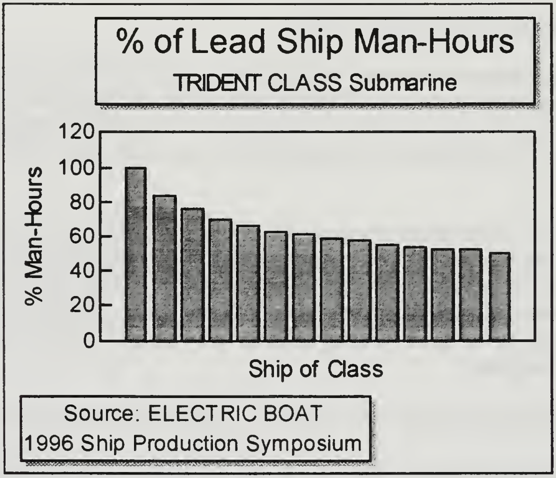

Figure 8-1 Follow-Ship Man-hours as a Percent of Lead Ship Man-hours

Figure 8-2 presents the learning curve used in this thesis compared to the learning curve experienced by Electric Boat.

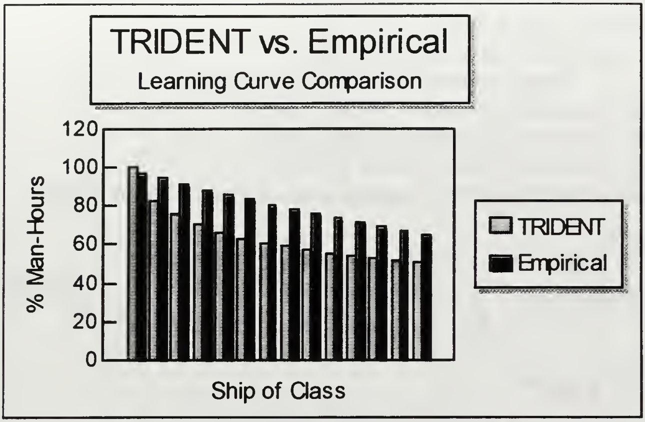

Figure 8-2 Thesis Learning Curve Vs TRIDENT Learning Curve

Since the number of modules used would be only a few compared to the eighteen TRIDENT Class Submarines built by Electric Boat[32], the 0.97 learning curve factor is considered conservative; the savings associated with fabricating identical structures is accounted for, yet the savings are not over-estimated. The corrected SWBS Group 100 cost includes the savings associated with using a parallel middle body, if appropriate.

The method to account for the cost savings associated with the parallel middle body is straightforward. The ASSET weight-based SWBS Group 100 cost is converted from a purely weight-based to a process-based estimate by substituting the processed-based costs for the weight-based costs for SWBS Groups 110, 130, 140. This is referred to as "$\$W_{100C}$" and is described on Line 1 of Figure 8-3. $\$W_{100C}$ is further adjustment to account for that portion of the ship which is parallel middle body (PMB). The ratio of the length of the PMB to the length between perpendiculars (LBP), rounded down to the next integer is determined and referred to as "Ratio". The quotient "PMB/LBP" is multiplied by the learning curve factor (LCF) raised to the "Ratio". Line 2 of Figure 8-3 describes the formulation of "$\$PMP_{100}$". "$\$PMP_{100}$" is the sum of that portion of the ship unaffected by the parallel middle body ("1-PMB/LBP") plus the parallel middle body (("PMP/LBP*LCF^Ratio"). The final, corrected SWBS Group 100 cost is referred to as "$\$CORR_{100}$" The process is shown in Figure 8-3.

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32 Although there were 18 TRIDENT Class Submarines built, data for only 14 were provided by Electric Boat.

1. $\$W_{100C} =$

[ASSET Group 100-
ASSET Group (110,130,140)+
Process-Based Group (110,130,140)]

PMB = Length of Parallel Middle Body
LBP = Length of Parallel Middel Body
LCF = Learning Curve Factor (0.97)
Ratio = PMB/(module length) rounded down to next integer

2. $\$PMP_{100} =$

$$\$W_{100c} * \left(\left(1 - \frac{PMB}{LBP}\right) + \left(\frac{PMB}{LBP}\right) * LCF^{Ratio} \right)$$

3. $\$Corr_{100} =$

$$\left(\text{ASSET SWBS 100 Cost]} - \text{[Weight-based SWBS 110,130,140]} + \$PMP_{100} \right)$$

Figure 8-3 Accounting for Parallel Middle Body

Since FSC has a parallel middle body in each of the three cases described below, there is no cost difference.

8.2 The As-Suggested ASSET Design

Since ASSET is the synthesis tool for FSC, the structural shapes suggested by its HULL STRUCTURAL Module are used as a reference.[33] The midship section module, as modeled by ASSET has many unsatisfactory limit state adequacy parameter values.[34] Girders are placed, as suggested by DDG-51 Detail Design, at the centerline and at 1/3 and 2/3 the width of the ship's beam.

Figure 8-4 shows the midship section as modeled in ASSET, whereas Figure 8-5 shows the midship section as modeled in MAESTRO.

33 The structural shapes suggested by ASSET are not always satisfactory when analyzed for structural integrity.

34 For definitions and application of limit state adequacy parameters, see Volume 1, Chapter 3 of the MAESTRO Users Manual.

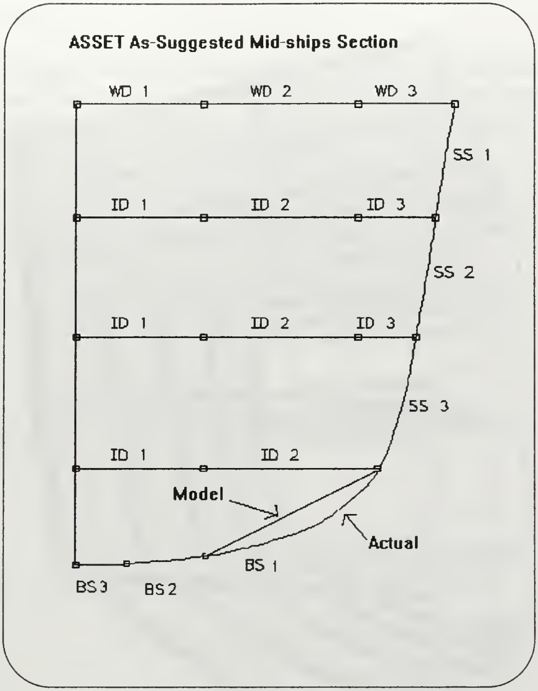

Figure 8 - 4 As-Suggested ASSET Model

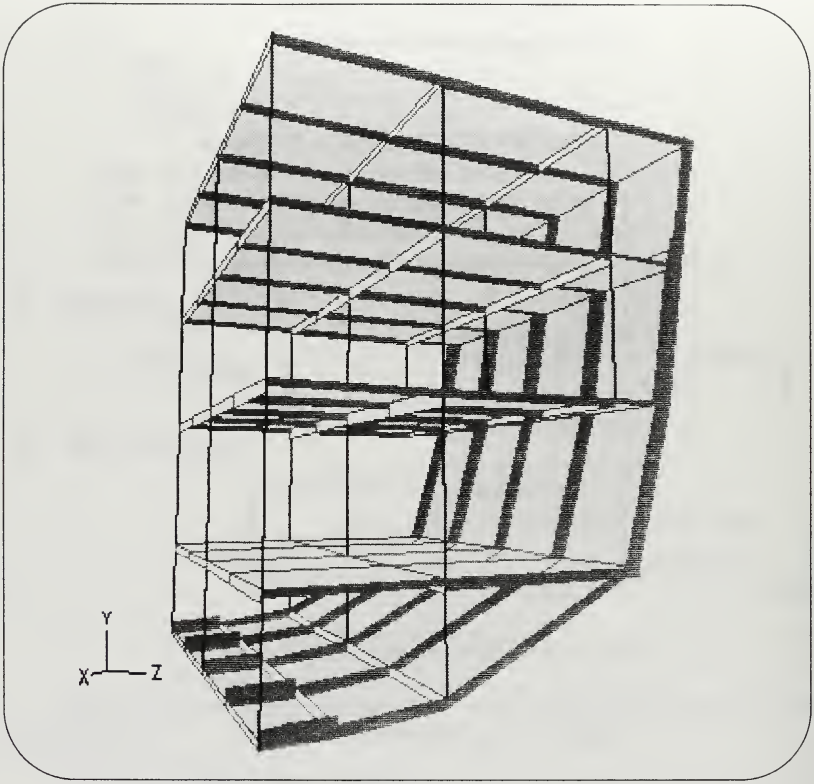

Figure 8- 5 ASSET As-Suggested Midship Section

The ASSET structural model suggested 20 different "I-T's" for use. The as-suggested ASSET structural shapes are listed in Appendix 9b. For this design alternative, 44 of 513 adequacy parameter values are inadequate based on a MAESTRO analysis. The histogram of adequacy parameters for the structural model suggested by ASSET is presented in Appendix 9b.

8.3 The Adequate ASSET Design

The ASSET segment endpoints are revised to better represent the radius bilge which begins below the Third Deck. A new endpoint was added to break the third member of the Bottom Shell into two segments. Figure 8-6 shows the revised model, whereas Figure 8-7 shows the revised MAESTRO model.

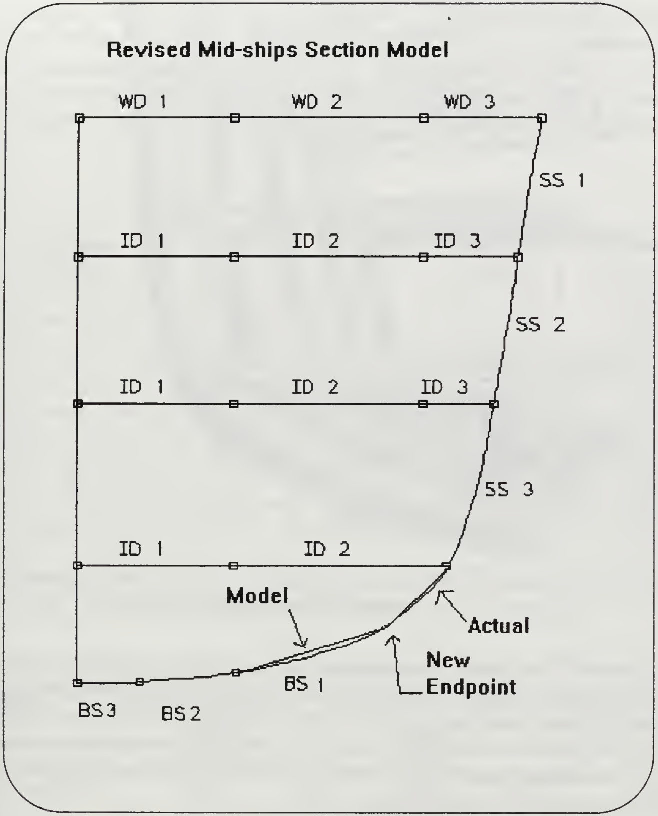

Figure 8-6 Revised Midship Section Model

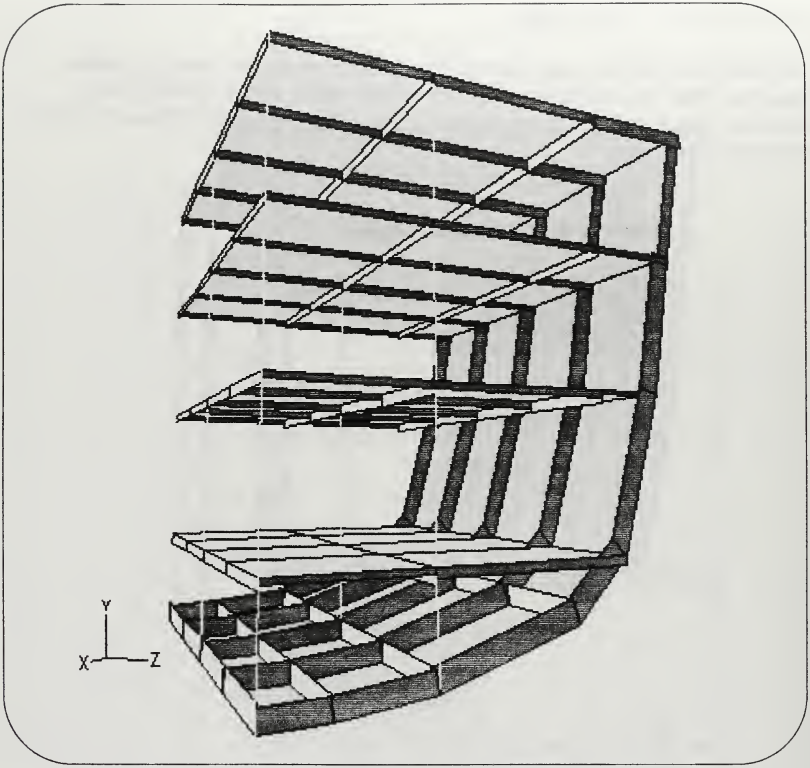

Figure 8-7 Revised MAESTRO Midship Module

To satisfy the limit state adequacy parameters, structural shape sizes are increased. Where possible, the as-suggested structural shapes are left unchanged. When size increases are required, the ASSET structural shape catalogue is used. In order to keep the overall module weight low, the as-suggested plate thicknesses are used. A total of 19 different sizes of structural shapes are required to satisfy the adequacy parameters. A table of the structural shapes, the number of uses, and a histogram are presented in Appendix 9c.

Despite increases in structural shape size and reduction of structural shape spacing[35], increases in the Weatherdeck 3 and Side Shell 1 plate thickness are required to achieve satisfactory limit state adequacy parameters. There are 5 different plate thicknesses used in this design. A table of the plate thickness is presented in Appendix 9c.

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[35] For Side Shell 1; as-suggested structural shape separation ~25 inches for 5 stiffeners, reduced to ~ 21 inches for 6 stiffeners.

8.4 The Producible Design

For the Producible design, only two plate thicknesses are used, 7/16 and 5/16 (0.4375 and 0.3125). Thicker plate is used externally (weatherdeck, side shell and bottom shell) and thinner plate internally (decks). Girders are placed at the centerline and at 1/3 the width of the ship's beam; the 2/3 width girders are not required.

"T-beams" are used for stiffeners, girders, and frames. A stiffener spacing of 28 inches is modeled. The T's are produced by splitting "IT" beams, as opposed to "I-T" beams which are produced by de-flanging. A reduced selection of "IT" beams is used from which to make selection. This selection, and the methodology to prepare it, are presented in Appendix 9d. There are eight different "ITs" used in the midship section. Frame spacing is 8-feet. These are listed in Table 8-1.

Table 8-1 FSC Structural Shape Sizes (inches)

Number of Uses	Height Web	Thickness Web	Breadth Flange	Thickness Flange
17	1.87	0.25	4.015	0.315
8	2.3625	0.25	4.02	0.395
4	2.87	0.26	4.03	0.425
3	3.75	0.3	6.685	0.43
4	5.64	0.44	8.99	0.68
8	6.36	0.49	9.99	0.745
2	7.85	0.605	11.54	0.96
3	8.4925	0.83	12.18	1.36

The weight of the module As-Suggested and revised "Traditional" module weights are compared to the "Producible" module weight in Table 8-2.

Table 8-2 Comparison of SWBS Group 110, 130, 140 Weights

Design	Module Weight (lton)	SWBS 110, 130, 140 Weight	Percent Increase (%) above Prediction
ASSET - Inadequate	115.6*	945.2**	0
ASSET - Adequate	126.85	1,037.2	9.7%
Producible	130.5**	1,067	12.9

* The Module weight was calculated based on summing the weights of the structural shapes in the modified NSRP 0405 spreadsheet.
** The ASSET SWBS 110, 130, 140 Combined Weight includes an 8% weight increase over that value calculated by ASSET. The 8% weight increase is a estimate value used as a result of the trade-off study.

The modified spreadsheet man-hour estimates and high-level process factors for the "Traditional" and "Producible" design alternatives are presented in Table 8-3.

Table 8-3 Comparison of Traditional and Producible FSC (man-hours)

Process	FSC - Traditional	FSC - Producible	Process	FSC - Traditional	FSC - Producible
Mat'l Rec & Prep	76.89	43.12	Scant Direct Labor	7,373.76	6,729.3
Auto Flame Cut	35.2	35.2	Scant Indirect Labor	1,843.44	1,682.32
Man'l Flame Cut	42.07	41.06	Scant Total Labor	9,217.2	8,411.62
Edge Prep Flat	208.97	214.55	Scant Labor $	345,645.17	315,435.84
Edge Prep Vert	14.6	2.04	Plate $	35,419.82	39,218.15
Edge Prep Ovhd	0	0	Stiffener $	15,710.77	7,727.67
Shape - Roll	4.02	4.08	Frame $	19,705.96	9,406.67
Shape - Line Ht	45	45	Mat'l $	70,836.55	56,352.49
Fit-Up & Ass'bly	2,254.52	2,230.35	Scant Total $	416,481.72	371,788.32
Distortion	649.79	601.85	Tube Total Labor	53.69	41.77
Auto - Fillet	282.64	270.58	Tube Labor $	2,013.37	1,566.56
Auto -Butt	552.96	552.96	Tube Mat'l $	8,785.35	3,319.95
Man - Fillet D*	425.24	425.24	Tube Total $	10,798.72	4,886.51
Man - Butt D*	1,243.42	969.1	Module $	427,280.44	376,674.84
Man - Butt V*	93.05	90.99	Scant Wt (both)	107.24	123.1
Man - Butt O*	0	0	Tube Wt (both)	19.61	7.41
Marking	27.69	21.22	Module Wt (both)	126.85	130.51
Store	26.22	15.31	MAESTRO Wt	105.5	127.6
Transport	138.42	106.08	Plate &Shape Mat'l/Labor	0.2	0.18
Lift	143.32	125.75	Tube Mat'l/Labor	4.36	2.12
Blast	554.87	467.41	Total Mat'l/Labor	0.23	0.19
Coating	554.87	467.41	Plate & Shape mhr/lton	171.89	136.67
			Tube mhr/lton	2.74	5.64
			Total mhr/lton	73.08	64.77
			Plate & Shape mhr/lton*	153.72	122
			Total mhr/lton*	65.4	57.86

Once the module cost is estimated, the remainder of the ship's structural cost must be estimated. This is accomplished by considering the portion of the ship which was modeled as the midship section is representative of the remainder of the ship. The portion of the ship which has received the benefit of process-based cost estimation is added to the weight-based cost estimation for the remained of SWBS Group 100, and the rest of the ship.

Since ASSET is the synthesis tool, and since many of its algorithms, including cost, are weight-based, an adjustment must be made to "correct" the structural weight determined by the ASSET WEIGHT Module. So after "correcting" the structural weight, not only will the weight be a better estimate, but those other parameters determined by the synthesis tool which are weight-related, (displacement, wetted surface area, resistance, seakeeping, stability etc.) will be better estimated.

The method of "correcting" ASSET is by the use of its Payload and Adjustment Table. Using this table, correcting a value determined by an ASSET module can be made in one or both of two ways. The first method involves either adding or subtracting a fixed value to that determined by ASSET. The second method involves taking the value determined by ASSET and multiplying it by a fixed ratio. It is the latter method which is used in this thesis.

The ratio of Producible Module weight to Traditional (and structurally satisfactory) Module weight is determined. This factor is considered to be representative of the ratio for each of the following SWBS Groups: 110, 130 and 140. This ratio is used to adjust the ASSET Payload and Adjustment Table (P&A). After adjusting the P&A table, the ship is run through a synthesis loop and balanced. The results achieved by balancing the ship are used to characterize the Producible Design Alternative, when compared to a Traditional Design Alternative.

Therefore, all other things being equal, a Traditional Design Alternative and a Producible Design Alternative will be identical except that the Producible variant will likely have a deeper draft than the Traditional Design since the structural weight is likely to be larger[36]. In the event that the Producible variant is heavier, this could lead to improved seakeeping, slightly reduced sustained and maximum speeds, shorter fuel endurance and perhaps larger life cycle fuel costs.

As far as estimating the SWBS Group 100 cost, the method is outlined below (all SWBS Group costs are determined using the ASSET COST Module):

a) determine the ASSET weight-based cost for SWBS Groups 110, 130 and 140, by considering all structural costs scale with weight;

b) subtract this weight-based cost from the Group 100 cost;

c) add the process-based cost (scaled from the module weight to the full Group 110, 130, and 140 weight), including the cost savings associated with the use of parallel middle body, if used. This is the "corrected" Group 100 weight

d) determine the Basic Cost of Construction (BCC), using the adjusted Group 100 cost instead of the weigh-based cost.

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[36] The term "likely" is used here since it is not a forgone conclusion that in no cases could the thick-plate, Producible Design be lighter than the Traditional Design.

Table 8-4 Effect of Heavier Hull Structure on FSC Performance

Category	FSC - Traditional	FSC - Producible	Savings
Draft	18.32 feet	18.37 feet	(~ 0.5 inch)
Maximum Speed	31.9 Kt	31.8 Kt	(~0.1 Kt)
Bales Seakeeping Index	13.16	13.19	0.03
Plate &Shape Fabrication Man-hours	9217 man-hour	8411 man-hour	806 man-hour
Material Cost	\$70800	\$56350	\$14450
Module Cost	\$427300	\$376700	\$50,600
SWBS 100 Cost Weight-Based	\$23.46 Mdol	\$23.72 Mdol	(\$0.4 Mdol)
SWBS 100 Cost Process-Based	\$23.14 Mdol	\$21.32 Mdol	\$1.7 Mdol
BCC Process-Based	\$232.7 Mdol	\$231 Mdol	\$1.7 Mdol
BCC Weight-Based	\$233 Mdol	\$233.4 Mdol	(\$0.4 Mdol)
Energy Cost** (total) {discounted}	3042 Mdol {210.0} Mdol	3042 Mdol {210.0} Mdol	~ \$0.0 Mdol
Producible Structural Design Cost Savings Compared to Weight-Based Cost		**\$2.4 Mdol**	

*Discounted Energy Cost formula discussed in Appendix 9d

8.5 Summary

The Producible FSC structural design achieves satisfactory structural integrity and has a lower BCC compared to the Traditional FSC structural design. Table 8-5 compares the process-based cost estimate for the Producible FSC to the weight-based cost estimate.

Table 8-5 Savings due to Process-Based Cost Estimation

Weigth-Based BCC	Process-Based BCC	Savings
\$233.37 Mdol	\$230.97 Mdol	\$2.4 Mdol

Further study is appropriate for alternative stiffener and frame spacing, and the use of bulb-T's instead of "ITs".

Chapter 9. Design for Environment

Design for Environment (DfE) is a relatively new field, developed in parallel to pollution prevention (PP). The goals of DfE and PP are to minimize raw material consumption, energy and natural resource (such as water) consumption, waste/pollution generation, health and safety risks, and ecological degradation over the entire life of the ship (EPA 1993); however, the methods to achieve these goals are different. The distinction between pollution prevention and DfE is found in the following definitions:

> Pollution Prevention (PP): Source reduction and other practices that reduce or eliminate the creation of pollution through increased efficiency in the use of raw materials, energy, water or other resources, or protection of natural resources by conservation. PP is traditionally focused on existing waste streams (Dorsey).
>
> Design for Environment (DfE): The practice of designing a project with the entire life cycle in mind. The design created meets, or at least addresses, all relevant environmental criteria while still satisfying all other important functions. The design identifies anticipated waste streams and attempts to exclude, limit, or substitute for all hazardous/polluting materials in all phases of the project's life[37] and in secondary waste streams necessary to support the project.

PP and DfE both are concerned not only with minimizing waste/pollution exiting a particular process or facility, i.e. a shipyard, but minimizing the materials going into and consumed by the entire process - upstream and downstream of new construction. From a regulatory perspective, the tern "waste minimization" is applicable to hazardous waste only, whereas PP broadens the concept to include the elimination of all waste/pollution (hazardous and non-harzardous) to all media (air, land, water, space).

The main point to understand is that unless all waste/pollution streams are identified and their impact accessed, continuing to focus on what have traditionally been the trouble-spots for the shipyard may be extremely short-sighted. When identifying the waste/pollution streams, it is important to look at the streams generated by suppliers and vendors to the shipyard and the disposal of consumed products used during the life of the ship and the ultimate disposal of the ship. This concept is developed in paragraph 9.2. It is recognized, however, that not all streams could receive a complete pollution prevention assessment and analysis. Prioritizing the streams by volume, consequence, public visibility, cost of mitigation, availability of suitable substitute material/process, etc. will establish the boundaries for spending PP budgets.

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[37] Phases of a project's life include all design stages, fabrication of individual components, installation and erection of the ship, customer use and support of the ship during its useful life and finally its disposal.

Like producibility, PP can and should be designed into a ship through the application of DfE. And, like producibility, incorporating PP while the design is developing and flexible is the only real opportunity to ensure positive steps are taken. PP does not, however, take precedence over the technical or mission-related requirements of a ship . PP must be considered along with cost, schedule, risk and mission performance. DfE can only be successfully integrated into a ship design if performed through the application of concurrent engineering.

9.1 Benefits of DfE

Some of the benefits of DfE are to:

- lower life cycle cost;
- outpace emerging and forecasted environmental regulations;
- conserve energy and other natural resources;
- simplify environmental management;
- provide an incentive for developing innovative clean technologies.

By applying a process-based cost estimate method to structures, the stage is set for extension to environmental concerns. Applying some sort of environmental score to each process and quantifying the impact is a logical extension of the process-based cost estimation methodology.

Each structural process factor could be considered a "mini-pollution stream". The mini-pollution stream could be analyzed to determine the categories of pollution caused directly and indirectly by each activity. For the purposes of this thesis, pollution is defined as any emission, effluent, spill, discharge, or disposal to air, land or water, whether routine or accidental. This includes waste which might otherwise be considered a normal by-product of an activity and which is currently not controlled by environmental regulations.

Un-treated emissions, by-products, waste and fugitive discharges caused directly and indirectly by the activity could be individually analyzed. Direct pollution, for the purposes of this thesis, is that created directly by the shipyard, and indirect pollution is that created by <u>all</u> vendors and suppliers (including the Navy itself) supporting ship construction. Effluents[38], direct and indirect, could be similarly analyzed on an individual basis.

If the impact of each pollution stream could be quantified in dollars, the environmental cost could be merely an additional process to be considered in the modified spreadsheet or a multiplier to the existing process factors. However, obtaining consensus on the dollar cost of a particular pollution stream other is not, in my judgment, possible given the broad nature of the stakeholders[39] involved.

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38 Effluents are defined as <u>treated</u> wastewater or airborne emissions discharged into the environment.

39 The sum of all stakeholders involved is <u>at least</u> the entire tax-paying population of the United States.

A more achievable method of including the environmental impact of structural fabrication steps would be to determine a relative environmental consequence or damage factor for each process. The sum (or product, perhaps) of these consequence factors would be a measure of the relative risk of a particular design. And, like the cost estimate, the environmental consequence could be used as a measure of the overall performance of the ship design. If the environmental consequence is unacceptable, the process-based arrangement would easily facilitate conducting a sensitivity analysis. By considering PP at concept design, especially in a process-based manner, a sensitivity analysis can be conducted to identify and take actions to mitigate the most environmentally insulting activities.

By re-arranging the process-based cost estimate method developed in this thesis to include a measure of the relative environmental impact, benefits for processes which take positive PP measures could be accommodated. Incentives could be instituted for:

- use of recycled or reused material;
- substitution of high-toxicity for low-toxicity products and processes, where appropriate;
- selection of suppliers with demonstrated low-impact operations and above average compliance records;
- substitution of controls/processes which make spill or fugitive releases less likely, such as painting components at the component manufacturer in closed paint booths, rather than after landing on foundations prior to erection.

All of these could be factored into the scheme. Further, penalties could be included for those processes which are environmentally egregious. In this manner, incentives for developing innovative, clean technologies could be factored into the method.

The environmental cost estimate could apply energy, waste/pollution and natural resource budgets to each process factor and monitoring these budgets as fabrication progresses. And, similar to the original NSRP 0405 spreadsheet, as natural resource and energy consumption, and waste/pollution generation is moved from locations of controlled environments such as panel lines and fabrication facilities to progressively more exposed area, such as sub-assembly, assembly and erection sites, the environmental consequence factors (and especially the penalty factors) grow.

9.2 How DfE Affects Total Ship Cost

It has been repeatedly shown that when DfE has been incorporated into a project, the life cycle cost is reduced. Dupont applied an environmental review procedure to the design of a new chemical facility. The process took 1,500 man-hours at a cost of $150,000, or 2 percent of the pre-project design cost. As a result of DfE, three major design modifications were implemented, having a combined internal rate of return of 45 percent at a net present value of $6.4 Mdol. At the same time, estimated organic air emissions were reduced by 99 percent (Kraft 1992).

The use of thicker plate in ship construction which leads to less paintable area which ultimately only receives a cleanliness condition of SP-3 instead of the desired SP-10 is an example which could ultimately prove to have even more advantages than those developed in the preceding chapters. Because there is less weld distortion to correct, there is less requirement for solvent and other surface preparation chemicals and consumables. Less area to be flame straightened leads to a reduction in the amount of burned charred epoxy paint and insulation, both of which have toxic emissions when burned. Further, since less of these high-VOC items require rework, there is potential for significant reduction in the use of these high-cost and high-labor intensive items. The better initial cleanliness achieved at new construction leads to better paint adherence, longer times between maintenance and fewer consumables (VOC containing paints, solvents and adhesives) in the future.

By designing beyond what is currently regulated, costly future back-fits to a ship can be avoided as environmental laws become more stringent and comprehensive. Using the process-based methodology, shipbuilders can identify where in their facility capital improvements (often charged against the Navy) are required anticipating future environmental regulations and the financial penalties associated them.

DfE includes resource and energy conservation as part of the strategy. Energy efficiency can be a positive strategy toward PP, but is often only a side benefit. By using less energy, either in a process controlled directly by the shipbuilder or indirectly by suppliers and vendors, pollution associated with the generation of electricity is reduced. Additionally, producing less waste in the mini-pollution streams means less energy is consumed processing, disposing and handling non-value-added products of shipbuilding. Therefore, applying DfE to ship structures to conserve energy and to reduce mini-pollution stream volumes leads directly to a cost savings.

Another cost savings associated with DfE and PP is simplified environmental management. With less waste to mange, less time is required for permitting, reporting, monitoring, testing, labeling, training, record keeping and inspecting (EPA 1992, 1994). As the Navy is experiencing with the high costs of decommissioning nuclear powered submarines which are laden with PCBs in insulation and gasket material throughout the ship, failure to DfE could have a significant impact on the cost of managing and disposing of ships in the future.[40]

An example of a possible future troublesome activity is any combustion or incineration process, i.e. welding and flame straightening, which produces Dioxin. In his paper "Dioxin Risk Re-assessment and Regulations," Dr. Yves Tondeur reported that federal guidelines for the control of dioxin in the Clean Water Act, the Safe Water Drinking Act, the Resource Conservation and Recovery Act and the Clean Air Act are scheduled to have substantial changes in the levels of dioxin above which control procedures are required. The anticipated reduction change in the levels could be by as large a factor as 1000. In some cases this could take the

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[40] Bill Birch of Puget Sound Naval Shipyard reported during a panel discussion at the Maritime Environmental Symposium 1995 (Arlington, VA) that $800 per lton were required to dispose of PCB waste.

maximum levels to just above the level detectable by the most sophisticated detection methods available. If these changes were to come to fruition, the regulatory and cost impacts, and the long term implications for shipbuilding and disposal, could be enormous.

It may be necessary and appropriate,, for example, for shipbuilders to apply PP incentives/penalites on sub-contractor contracts as a method of achieving the desired total effect on the ship.

9.3 Summary

The application of a continuity-of-mass approach throughout the entire shipbuilding process could reveal the full waste/pollution stream of designing, building, maintaining and disposing of a ship. Evaluating the consequences of these streams is not an easy problem, yet can not be ignored. A detailed continuity-of-mass approach would likely be cost prohibitive, yet identifying the most environmentally insulting processes, on the shipyard or by its vendors/suppliers, would not be onerous. In fact, the New Attack SSN program (Smith) has done just that.

DfE could reduce ship construction cost and life cycle costs, particularly if environmental consequence factors are considered along with the process-based cost estimate method developed in this thesis. While the current complex matrix of environmental laws do not require designing ships to be "green", it is prudent to include the environmental impact/consequence and cost in the concept design analysis, anticipating that during the 40-year life of the ship, environmental and health priorities may change.

Some immediately recognizable DfE changes suggested in this thesis are:

- use of IT instead of I-T:

  a) this substitution reduces the paintable surface area to achieve the same moment of inertia about the toe of the "T-beam";
  b) eliminates large quantities of scrap steel
  c) reduces the energy costs associated with producing a structural member, since 2 "T-beams" are formed by a single cut using IT, whereas 2 cuts are required to form a single "T-beam" using I-T;
  d) a reduction in the amount of fresh water, and sewer water required to be processed by the shipyard since there will be less water used to cool flame-straightened steel and therefore less run-off.

- use of thick plate:

a) reduces the need for flame straightening, strongbacks or saddles, thereby reducing the energy consumption associated with these activities;

b) reduces the amount of re-preparing, re-preserving, re-painting on the ship, thereby reducing VOC emissions, spillage and consumption of consumables

c) reduces the paintable surface by allowing the use of smaller structural shapes;

d) avoid the need for cut-outs through large structural shapes, this further reduces the amount of waste and consumption of energy, and reduces the paintable surface area. Further, the fewer number of cut-outs reduces the number of potential preservation problems so often associated with sharp, small radius corners in steel strength members;

e) reduces the need to establish ventilation barriers which vent toxic off-gassing away from nearby workers while flame straightening in enclosed spaces shipboard. This reduces the amount of consumables such as tape, adhesives, plastic sheeting, personal protective equipment and the like.

- use of special catalogue listing only certain structural shape sizes:

a) allows for Just-In-Time delivery reducing the transportation and lifting requirements which are large energy consuming activities;

b) allows more efficient use of storage space, potentially covered or enclosed, thereby reducing the tendency for corrosion which must be removed prior to fabrication.

- use of HTS:

a) prevents the need for pre-heat associated with HY-80, thereby lowering energy costs;

b) allows more accuracy control of welding design and welding practices, thereby reducing the requirements for special welding consumables, some of which are known to have trace quantities of heavy metals or metals which are of environmental concern.

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Chapter 10. Summary, Conclusions and Suggestions for Future Work

10.1 Summary

There is a significant need, and accompanying significant challenge, to concurrently consider performance, cost and production issues from the very beginning of the design process. The greatest obstacle to this approach is the lack of convenient and effective cost and performance models that can be integrated into a seamless design workbench accessible to working engineers. Traditional models and analysis methods frequently do not provide the sensitivity necessary to consider all the important variables impacting performance, cost and production. Unfortunately, achieving this sensitivity at the concept design stage almost requires a detail design level of analysis. Quick-look studies which currently are accomplished using parametric-based tools do not have this sensitivity.

The traditional design method does not adequately include production engineering or material/supplier/logistical concerns early enough to have a substantive, positive impact on the design. Taking an integrated approach, and using computer-aided cost, analysis and synthesis tools can mitigate these traditional design process failures.

Innovation is required in structural design and cost estimation. The use of concurrent engineering, and in particular a process-based design and cost scheme, in concept design is the solution to reducing errors during production caused by design errors, to reduce the overall design time and to shorten the build cycle for naval ships.

This thesis has developed a method to integrate an existing naval ship concept design synthesis tool (ASSET) and a commercial finite element structural analysis program (MAESTRO), with refinements to an existing structural construction cost estimating program (NSRP 0405). The integration of these separate programs provides the designer with a method of assessing the process-based cost and performance impacts associated with certain structural and hull form parameters which affect or enhance producibility. The structural parameters considered here are plate thickness, variety and number of structural shape sizes, and the use of parallel mid-body. Hull form concepts considered include shear, camber, and gaussian curvature.

The major benefit of this integrated tool is that it allows some assessment at the concept design stage of the cost impact associated with details often not considered until the detailed design stage. The following producibility issues are specifically addressed in the cost estimate tool developed in this thesis:

- process-based cost algorithm
- cost of weld distortion accounted for
- producibility impact of using a parallel middle body
- producibility impact of using flat surfaces above the waterline

Conclusions

1. It is necessary and possible to account for the cost of removing distortion caused during structural fabrication during concept design.

2. "ITs" are acceptable for structural integrity, have less paintable surface area and are most cost effective than "I-Ts".

3. The use of a producible structural design concept (heavy plate/small structural shapes) instead of the traditional structural design concept (thin plate/heavy structural shapes):

a. is structurally adequate;
b. is more cost effective;
c. has little or no impact on ship performance if considered from the beginning of concept design.
d. using structural shapes sized for producibility, cut-outs for distributed systems through structural shapes are avoided. Distributed systems may be suspended below structural members thereby greatly improving producibility and repair.

4. It is possible to account for the cost savings due to the use of parallel middle body during concept design.

5. Process-based material cost estimation is possible, relatively straight-forward and directly applicable to process-based man-hour estimate methods.

6. In the aggregate, the detailed process-based estimates developed compare favorably with weight-based, high-level man-hour per lton estimates.

7. The application of DfE is easily facilitated using a process-based design philosophy, and contributes to reducing the acquisition and life cycle cost of a ship.

8. The use of process-based cost estimation is feasible during concept design, and enhances the overall all performance of the ship.

Suggestions for Future Work

The moment of inertia about the foot of the "T" is an equally important structural parameter compared to cross-sectional area. Re-plotting the cost information developed in this thesis against the moment of inertia, and producing a new empirical curve should be conducted.

The welding analysis feature of MAESTRO warrants investigation as it applies to process-based structural analysis.

A more sophisticated method to estimate the vertical bending moment to allow seamless integration with MAESTRO ".dat" files should be explored.

A detailed Analytical Hierarchical Process (AHP) survey should be developed and distributed to experts to:

a. explore the possibility that the process factor categories used in this thesis are inadequate or improper;

b. to properly quantify the adjustments made to process factors suggested in this thesis;

c. to validate the high-level process factors;

d. to validate the distortion model used in this thesis.

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Appendix 1 NSRP 0405 Computer Program Column Description

The NSRP 0405 Cost Estimating Computer Program creates unique spreadsheet forms for each of the following general categories: hull structure, heating, ventilation and air conditioning (HVAC), electrical and piping installation. The details of each general category differ, yet the layout and the central nine columns of all spreadsheets are the same.

The nine columns which warrant description are: Work Process, Work Units, Process Factor, Unit Amount, Actual Stage, Standard Stage, Actual Factor, Standard Factor, and Man-hours Required.

1. Work Process

All of the work processes which may be used to fabricate a generic interim product of a particular general category, say hull structure, are listed in this column. Not all work processes or work practices will necessarily be used on every interim product, but the intent is that all possible processes or practices be listed. This minimizes the manipulation of the spreadsheet, presents a standard format and provides a "standard" list of work practices for each general category.

2. Work Unit

For each Work Process, there is a Unit of Work which determines the magnitude of effort involved in that process. The work unit is a particular item specific to the general category. The work unit associated with "Cutting" pipe, for example, is the number of cuts to be made, while the work unit for "Fit-up, Assembly and Installation" of pipe is the number of joints.

3. Process Factor

This column listed the factor which must be applied to each work unit in order to determine the man-hours required to perform the task. The values in these columns of NSRP 0405 spreadsheets were determined based on discussions with individuals in private shipyards, estimates based on the authors personal experience, and from estimating standards used at Naval Shipyards. For more details on this matter, the reader is directed to the source document.

The process factor is determined by using a key parameter or characteristic of the interim product as an independent variable. The independent variable is used to enter a "look-up" table associated with each general spreadsheet category. The look-up table is located within the spreadsheet. The process factor for the key parameter is determined for the Standard and Actual stage of construction, and applied to the spreadsheet.

4. Unit Amount

The Unit Amount column is filled in for each design alternative considered.

5. Actual Stage

This is the actual stage of fabrication during which the specific work process was performed.

6. Standard Stage

This is the or standard stage of the production process where the specific work process "most desired" to be performed.

7. Actual Factor

This is the difficulty factor associated with performing the work practice at the actual stage of fabrication. See Figure A4-1.

8. Standard Factor

This is the difficulty factor associated with performing the work practice at the standard stage of fabrication. See Table 4a-1.

Table 1a-1 Construction Stages and Process Difficulty Factors

	Stage	Location	Difficulty Factor
1	Fabrication	In Shop	1
2	Pre-Paint Outfitting	On Plate Line - Hot Work	1.5
3	Paint	Paint Shop / Stage	2
4	Post-Paint Outfitting	On Platten - Cold Work	3
5	Erection	Erection Site	4.5
6	On-Board Outfitting	Erection Site	7
7	Waterborne	Pierside after Launch	10

9. Man-Hours Required

The information in the right-most column is calculated by the program. This information is the product of the process factor, the unit amount, and the ratio of Actual Factor to Standard Factor. Values of Actual Factor to Standard Factor which are less than 1.0 are not permitted by the program.

10. Cost Estimate

The program automatically sums all the man-hours of the right hand column. An allowance for trade support is determined based on a percentage figure. This trade support figure can be modified for specific needs. The total man-hours are multiplied by the hourly rate for the associated trades to calculate the labor cost.

Finally, the material cost is added to determine the total cost of the interim product.

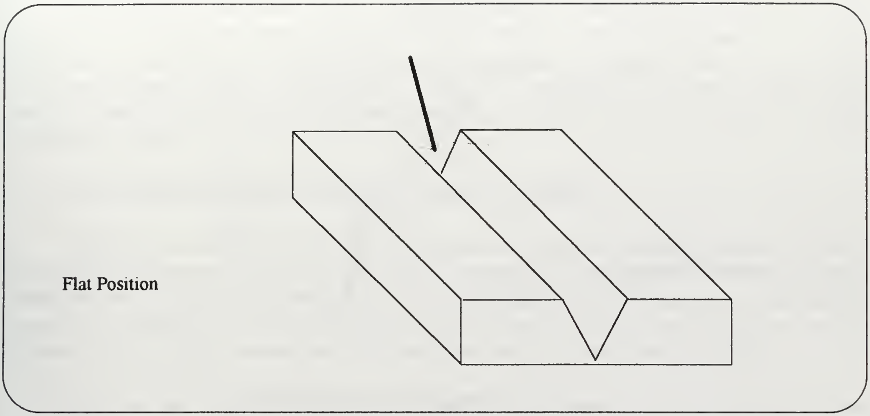

Figure 2a-1 Flat Position for Welding

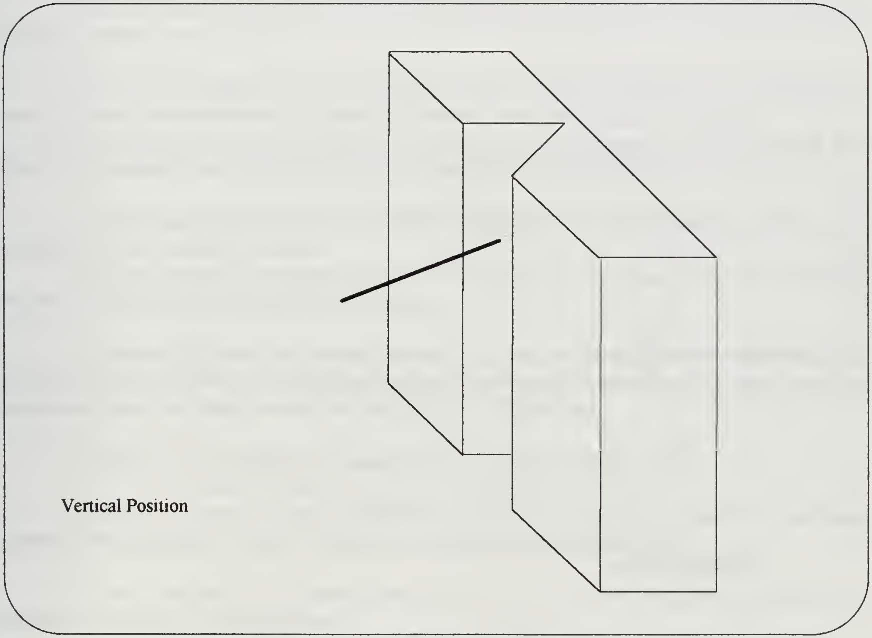

Figure 2a-2 Vertical Position for Welding

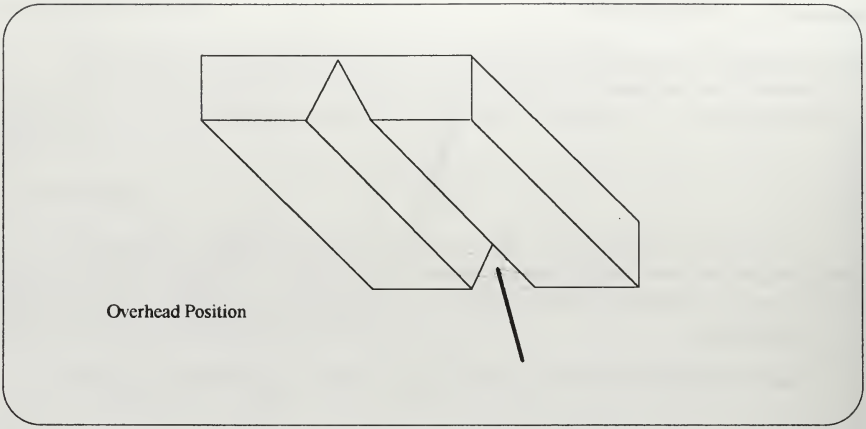

Figure 2a-3 Overhead Position for Welding

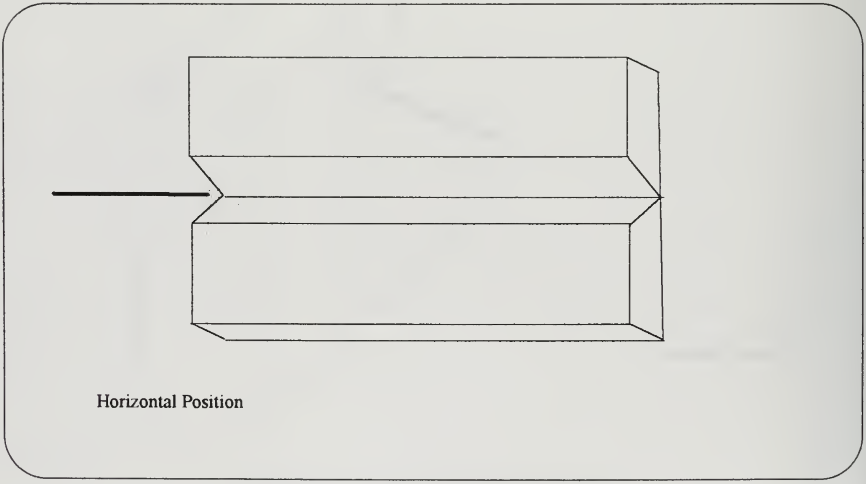

Figure 2a-4 Horizontal Position for Welding

Appendix 3 Basic Outline of Method:

A1. "Build" a ship using ASSET. A Payload & Adjustment (P&A) Weight Factor (WT FAC) and a P&A Vertical Center of Gravity Factor (VCG FAC) will be appropriate: if no other information is available, one should consider using the DDG-51 Flight IA ratios of ".2964" and ".985" respectively. (.2964= 3118.05/2405.1. This is "1 minus the ratio" of the GROUP 100 weights for the as built DDG-51 Flight IA and the DDG-51 Flight IA calculated using the ASSET internal algorithms)

A2. Synthesis of this ship is required, Balancing is required.

A3. Prior to leaving ASSET, view the midsection using the graphics function. Notice if the Side Shell 1 aligns with the first internal deck. For designs which use HY-80 as the Side Shell 1 material, the HY-80 to High Tensile Steel (HTS) transition often does not occur where the first Internal deck adjoins the side shell. Knowledge of this orientation is crucial when constructing the endpoints which will be exported from the spreadsheet into the MAESTRO ".dat" file.

B. From the output of ASSET's STRUCTURE Module, copy the offset information maintaining the order provided by ASSET.

C. Paste this information into the range provided in the modified NSRP 0405 spreadsheet (any cell generally below A250).

D1. Parse this information into the area provided in the spreadsheet. The spreadsheet is setup to revise the information to be useful for pasting into a MAESTRO ".dat" file.

D2. Apply your choice of stiffening elements, plate thicknesses, frame sizes and floor shapes and materials, and pillar (tube) sizes and materials to the spreadsheet.

E1. Copy the information from the MAESTRO sections of the spreadsheet and paste it to a simple text editor such as Notepad.

E2. Copy the desired information from the Notepad file and paste it into the appropriate sections of the baseline MAESTRO ".dat" file.

F. Process the ".dat" file through an analysis loop of MAESTRO. Correct shear and vertical bending moment at un-restrained section of module (if required) to achieve a near-zero unbalanced condition, often reported by MAESTRO as "High Cut".

G. View the MAESTRO results using MAESTRO GRAPHICS (MG).

H. Correct the material type and thickness, as well as the number and size of the stiffeners, girders, frames and pillars to meet the limit state criteria you have established.

I. After correcting the structural shapes, copy the now-correct structural shapes into the appropriate sections of the spreadsheet.

J. Parse the now-correct data into the appropriate sections of the spreadsheet. Care should be exercised to ensure the parsed data is correctly aligned with the desired rows in the spreadsheet.

K. Obtain the Module weight data from the MAESTRO ".out" file. Copy this value into the appropriate section of the spreadsheet.

L. Compare the MAESTRO weight data to that generated by the spreadsheet.

M. Determine the Module Weight's "Ratio to Baseline" (Variant weight compared to baseline) from the Summary spreadsheet.

N1. Enter this ratio, and any updated VCG information, into the GROUP 100 (HULL STRUCTURE) line of the P&A table of the variant ASSET file. Create three new lines, one each for GROUP 110 (SHELL and SUPPORT Structures), 130 (HULL DECKS) and 140 (HULL PLATFORM and FLATS). For GROUPs 110, 130 and 140, enter the WT FAC and VCG FAC calculated by MAESTRO and the modified NSRP 0405 spreadsheet. Re-Synthesize the ship, and attempt to avoid making any substantive changes to the characteristics of the ship without the additional GROUP 110, 130 and 140 weight. The ship will usually have a deeper draft due to the increased weight. A deeper draft usually means a larger wetted surface area, change in the stability, reduction in endurance and fuel capacity and slower sustained and maximum speeds.

N2. Run the Seakeeping Module. Record the Bales and McCreight Seakeeping Index Scores in the appropriate locations in the modified NSRP 0405 spreadsheet.

O. Run the cost model. The parameters used to obtain cost information for comparisons in this thesis are discussed in chapter 8.

P1. Sum the final ASSET GROUP 110, 130 and 140 weight; enter in the appropriate location of the modified NSRP 0405 spreadsheet.

P2. MAESTRO Data Group XIX allows an optional lengthwise distribution of weight, represented as a uniform distributed vertical force, one value per section interval or bay. Determine the distributed weight by subtracting the sum of (GROUP 110 plus 130 plus 140) from the Full Load Displacement. The Full Load Displacement may be found in report one (1) of either the HULL GEOMETRY MODULE or the DESIGN SUMMARY MODULE. Divide the residual weight by the Load Waterline (LWL), which is found in report one (1) of the HULL GEOMETRY MODULE. Convert this quotient to units consistent with those used by the MAESTRO ".dat" file; in the case of this thesis, the units were pounds per inch.

Q. Enter the final ASSET GROUP 100 weight in the appropriate location of the modified NSRP 0405 spreadsheet.

R. Enter the GROUP 100 Follow Ship cost (found in report #2 of the COST Module) in the appropriate location of the modified NSRP 0405 spreadsheet.

S. Enter the Basic Cost of Construction (BCC) (found in report #2 of the COST Module) into the appropriate row under the column labeled "Weight-Based Estimate BCC" of the modified NSRP 0405 spreadsheet.

T. Enter the Life Cycle Energy Cost (found in report #3 of the COST Module) into the appropriate row under the column labeled "LIFE CYCLE ENERGY COST" of the modified NSRP 0405 spreadsheet.

U. Enter the remainder of the principal characteristics from ASSET into the modified NSRP 0405 spreadsheet. These characteristics are Ship Displacement, Draft, GMT/B, Sustained and Maximum Speed, Range.

Note: When exporting data from a spreadsheet to a MAESTRO ".dat" file, it is often required to first paste the data into a simple editor such as Notepad, then cut or copy this data and paste it into a more sophisticated text editor (such as WORD or WordPerfect). If the data is pasted directly into the sophisticated text editor, some spreadsheet cell configuration information or text strings may be interspersed with the desired data. Pasting/Cutting the desired data through the simple text editor avoids bringing cell configuration information along with the desired data.

Note: Once the desired data is pasted into a sophisticated text editor (such as WORD or WordPerfect), remove the Hard Tabs and replace them with a space. The distinction between Hard Tabs and spaces is not readily discernible in an editor such as Notepad. The MAESTRO ".dat" file can not contain any Hard Tabs, their presence will cause the program to mis-count the lines of data.

Appendix 4 Method to Obtain ASSET Structural Shapes for Analysis

To obtain the Scantling values for each "Reference Variant" produced in ASSET, use the following procedure:

1. Produce and synthesize each "Reference Variant" in ASSET;

2. While yet in ASSET, "Set,Online,All". Note, for the analysis considered during the conduct of this thesis, Longitudinal and Transverse Bulkheads, and the stiffeners associated with these bulkheads, were not modified nor modeled; these items are described in Printed Reports 11, 12 and 15. These reports are deleted once the FOR007.dat file is opened in the text editor.;

3. "Run, Structure Module";

4. "Store (or Modify), 'FILENAME'";

5. Exit ASSET;

6. Open FOR007.DAT file in a text editor;

7. Find 'Printed Report No. 3 - WEATHER DECK';

8. Note the Deck and Stringer Plate Material Type;

9. At the end of each line of scantling data, add a hard tab followed by the Stiffener Numeric label, then another a hard tab followed by the Plate Numeric label;

10. Repeat the general procedure found in items 8 and 9 for each of the ASSET data which will be exported into the spreadsheet, and ultimately into MAESTRO. For GROUP 110, 130 and 140, the remaining reports which will require such editing are:
#4 (SIDE SHELL), #5 (BOTTOM SHELL), # 6 (INNER BOTTOM), and # 7 (INTERNAL DECKS).

11. To enhance the PARSE feature in the spreadsheet, use the "FIND/REPLACE" feature of your text editor to remove the following codes from these reports: "X" and "/".

12. Remove the NOTES provided by ASSET concerning whether the scantling shapes are rolled or fabricated.

13. Copy the streamlined, and enhanced, information from these reports to a new document in your text editor. The information should now be in a form similar to the following. I have added column labels to enhance clarity in this appendix, however, such labels should not be exported to the spreadsheet. Notice, the stiffener characteristics are order differently in the ASSET output file than are required by the MAESTRO ".dat" file. This matter is resolved within the spread sheet.

Appendix 5 Use of "Ranges" in Modified Spreadsheet

Concerning Ranges:

There are a variety of cells which contain information such as a lookup table. These are referred to as Ranges in LOTUS 1-2-3. The ranges which are used in the modified spreadsheet are described below. The "GO TO" function in LOTUS 1-2-3 should be used to find the ranges in the spreadsheets.

1. The location provided into which to copy the ASSET structural shape information is the Range "ASSET_Scantling".

2. The location provided into which to copy the ASSET girder information is the Range "ASSET_Girder".

3. The location provided into which to copy the ASSET frame information is the Range "ASSET_Frame" .

4. The Range "Tube" is a single cell, and marks the beginning of the section for tubes.

5. The modified NSRP lookup table "A" for HTS is named "A_Original".

6. The modified NSRP lookup table "B" for HTS is named "B_Original".

7. The PODAC study values suggested for substitution instead of the NSRP 0405 lookup table "A" is named "A-PODAC".

8. The PODAC study values suggested for substitution instead of the NSRP 0405 lookup table "B" is named "B-PODAC".

9. The original NSRP 0405 Pipe "A" lookup table is named "Lookup-pipe-A".

10. The original NSRP 0405 Pipe "B" lookup table is named "Lookup-pipe-B".

11. The original plate cost lookup table is named "Lookup_HTS_C" (underscores are correct).

12. The original weld distortion lookup table is named "Lookup_HTS_D" (underscores are correct).

13. The cost per man-hour ($37.5/man-hour) is named "RATE".

14. The sums of man-hours and other interesting values at the bottom of columns from BQ to EC are in a range, the range is named "xpose" (for transpose).

15. The location where the range "xpose" may be transposed to allow comparison to other design alternatives is named "xxpose".

16. A side-by-side comparison of design alternatives without the blank spaces found in ":xxpose" is named "progress" and is located near "xxpose"

Appendix 6 Detailed Description of Individual Cells of Modified Spreadsheet

The following section describes each cell of the modified spreadsheet for structural shapes and tubes.

A: Cell A250 is location into which the ASSET OFFSETS are copied. These OFFSETS which have been created by editing Reports 3,4,5,6 and 7 (Weather Deck, Side Shell, Bottom Shell, Inner Bottom and Internal Decks) of the ASSET STRUCTURES Module. Column "A" has notes in upper rows.

A1: Cell C12..I34 is the location into the ASSET OFFSET data is parsed. To avoid mixing new data with old, it is beneficial to remove the old data prior to parsing the new. The is best performed by highlighting the region into which the new data will go and "Delete" the data. "Delete" should be used and not "Cut".

B: Column of Labels for Structural Identifiers: Weather Deck, Side Shell, etc.

C: Unique sequential numbers for specific Structural Identifiers: WD1, WD2, WD3, SS1...,IB2..., ID3-2, etc.

D: The ASSET Y-axis (Transverse direction) value of the inboard location of the structural member of interest. Cells D39..D42 are formulated; they display the inboard ASSET Y-axis position of the Floors, if appropriate.

E: The ASSET Z-axis (Vertical direction) value of the inboard location of the structural member of interest. Cells E39..E42 are formulated; they display the inboard ASSET Z-axis position of the Floors, if appropriate

F: The ASSET Y-axis (Transverse direction) value of the outboard location of the structural member of interest. Cells F39..F42 are formulated; they display the outboard ASSET Y-axis position of the Floors, if appropriate.

G: The ASSET Z-axis (Vertical direction) value of the outboard location of the structural member of interest. Cells G39..G42 are formulated; they display the outboard ASSET Z-axis position of the Floors, if appropriate.

H: The ASSET pressure per square inch associated with the "HEAD 1" conditions.

I: The ASSET pressure per square inch associated with the "HEAD 2" conditions.

J: A column used to attempt to draw attention to the additional side shell plate which is often necessary for modeling purposes since Inner Deck 1 (ID1) does not always align with the HY80 to HTS transition which occur along the Side Shell.

K: The MAESTRO Y-axis (vertical direction) value of the inboard location of the structural member of interest.

L: The MAESTRO Z-axis (transverse direction) value of the inboard location of the structural member of interest.

M: The MAESTRO Y-axis (vertical direction) value of the outboard location of the structural member of interest.

N: The MAESTRO Z-axis (transverse direction) value of the outboard location of the structural member of interest.

O: The Node length of the structural member of interest. This value is obtained by assuming the plate has no curvature, and using Pythagorean' Theorem. The node length is the square root of the sum of the difference in Y-axis and Z-axis coordinates.

P: This column is supplied in an attempt to draw attention to the fact that additional nodes (referred to as endpoints in MAESTRO) which are not created by ASSET are created within the spreadsheet. These endpoints make modeling in MAESTRO more straightforward.

Q: The MAESTRO Y-axis endpoint value to export from the spreadsheet into the MAESTRO ".dat" file.

R: The MAESTRO Z-axis endpoint value to export from the spreadsheet into the MAESTRO ".dat" file.

S: This column supplies an "!" required in MAESTRO to facilitate adding text to the end (right hand side) of data.

T: This column identifies the MAESTRO endpoint number.

U: This column identifies the between deck height of the endpoint and deck position below the endpoint. For endpoints which are not associated with a deck, the between deck height displayed indicates the distance to the structural member for which a vertical distance would most likely be of concern. For example, for the distance associated with an inner bottom endpoint is that of the height the particular floor associated with the endpoint.

V: This column calculates the value obtained by dividing the Node Length by a 28 inch (28") stiffener spacing. Additional columns may be added to investigate stiffener spacing larger than 28 inches.

W: This column indicates the number of stiffeners along the structural member of concern using a stiffener spacing of 28". The value obtained in column V was rounded down to obtain this value.

X: This column calculates the value obtained by dividing the Node Length by a 26 inch (26") stiffener spacing.

Y: This column indicates the number of stiffeners along the structural member of concern using a stiffener spacing of 26". The value obtained in column X was rounded down to obtain this value.

Z: This column calculates the value obtained by dividing the Node Length by a 24 inch (24") stiffener spacing.

AA: This column indicates the number of stiffeners along the structural member of concern using a stiffener spacing of 24". The value obtained in column Z was rounded down to obtain this value.

AB: This column calculates the value obtained by dividing the Node Length by a 22 inch (22") stiffener spacing.

AC: This column indicates the number of stiffeners along the structural member of concern using a stiffener spacing of 22". The value obtained in column AB was rounded down to obtain this value.

AD: 1. For baseline determinations using un-modified ASSET structural shapes, this column displays the number of stiffeners calculated to be used by ASSET.

2. For modified baseline or variant determinations, this column represents the number of user-chosen stiffeners which are to be associated with the structural member of concern.

3. Note, for baseline spreadsheet and MAESTRO computations, the Minimum and Maximum Stiffener Spacing was designated as a user-defined input value in ASSET, and this stiffener spacing should be maintained in subsequent analyses.

4. In any case, this number is exported to/from the MAESTRO ".dat" file. Exported information from the MAESTRO file may be different as a result of Optimization or as required to satisfy the limit states.

5. The span (designated as RANGE "a") is labeled in this column.

AE: 1. This column supplies a null (0) entry necessary for MAESTRO Data Group IX, item 2.

2. Edge Stiffeners are normally to be avoided, and if a stiffener is to be required at the edge of the structural member of concern (e.g. at an endpoint) it is best to add a small girder there instead of an edge stiffener.

3. The RANGE "a" is defined in this column. For this thesis, the span is considered to be 8 feet, a common frame spacing.

AF: 1. For baseline determinations using un-modified ASSET structural shapes, this column displays the plate thickness ("t", in inches) exported from ASSET.

2. For modified baseline and variant determinations, this column identifies the user-defined plate thickness.

3. In any case, this data will be exported to/from the MAESTRO ".dat" file. Exported information from the MAESTRO file may be different as a result of Optimization or as required to satisfy the limit states.

4. The number of longitudinal sections (designated as RANGE "s") is labeled in this column.

AG: 1. For baseline determinations using un-modified ASSET structural shapes, this column displays the height of the stiffener web (HSW, in inches) exported from ASSET.

2. For modified baseline and variant determinations, this column is where the user defines HSW.

3. In any case, this data will be exported to/from the MAESTRO ".dat" file. Exported information from the MAESTRO file may be different as a result of Optimization or as required to satisfy the limit states.

4. The RANGE "s" is defined in this column. For this thesis, there are 4 longitudinal sections.

AH: 1. For baseline determinations using un-modified ASSET structural shapes, this column displays the thickness of the stiffener web (TSW, in inches) exported from ASSET.

2. For modified baseline and variant determinations, this column is where the user defines TSW.

3. In any case, this data will be exported to/from the MAESTRO ".dat" file. Exported information from the MAESTRO file may be different as a result of Optimization or as required to satisfy the limit states.

4. The RANGE "material" is labeled in this column.

AI: 1. For baseline determinations using un-modified ASSET structural shapes, this column identifies the breadth of the stiffener flange (BSF, in inches) exported from ASSET.

2. For modified baseline and variant determinations, this column is where the user defines BSF.

3. In any case, this data will be exported to/from the MAESTRO ".dat" file. Exported information from the MAESTRO file may be different as a result of Optimization or as required to satisfy the limit states.

4. The Numeric value for Mild Steel (MS) is assigned as one (1) in this column.

AJ: 1. For baseline determinations using the un-modified ASSET structural shapes, this column identifies the thickness of the stiffener flange (TSF, in inches) exported from ASSET.

2. For modified baseline and variant determinations, this column is where the user defines TSF.

3. In any case, this data will be exported to the MAESTRO ".dat" file. Exported information from the MAESTRO file may be different as a result of Optimization or as required to satisfy the limit states.

4. The Numeric value for High Tensile Steel (HTS) is assigned as two (2) in this column.

AK: 1. This column supplies an "!" required in MAESTRO to facilitate adding text to the end (right hand side) of data.

2. The Numeric value for High Yield 80 Steel (HY80) is assigned as three (3) in this column.

AL: 1. This column identifies the abbreviation of the structural member of concern (e.g. a stiffener in cell A12). It is copied from the spreadsheet to the MAESTRO ".dat" file, and its presence in the ".dat" file facilitates easy editing.

AM: 1. This column identifies the stiffener structural shape used to create the dimensions of the stiffener.

2. "IT" is a I-shaped stiffener (else where known an I-beam) which has had its web split to form two (2) T-shaped stiffeners.

3. "I-T" is a I-shaped stiffener which has been de-flanged. De-flanging results in a T-shaped stiffener and two pieces of scrap.

AN: This column repeats the number of stiffeners chosen in column AD.

AO: This column is where the stiffener material is displayed or designated using the numeric identifiers provided starting in column AH1.

1. For un-modified baseline determinations, the value displayed is the numeric identifier the user added to the structural shape data while the data was yet in a sophisticated text editor. Each of the ASSET HULL STRUCTURES Reports indicates the plate and/or structural shape

material appropriate for the report. Note, the ASSET material selection is user-defined. Once the ASSET data is parsed into the spreadsheet, the material selection is automatically copied into this column.

2. For modified baseline and variant determinations, the stiffener material selection is input into this column.

3. If as a result of MAESTRO analysis, the material has changed, care should be taken to ensure the proper material numeral appears in this column for each plate.

AP: 1. This column calculates the linear feet of stiffener used in the module. The value is obtained by multiplying the Number of Stiffeners Chosen (AD) by the span (AE2, "a"), which in turn in multiplied by the number of longitudinal sections (AG2, "s") in the module.

A*S*AD8

2. The total linear feet of stiffeners for the module is summed immediately below the individual section computations.

AQ: 1. This column calculates the square feet of stiffener used in the module. The value is obtained by multiplying the Number of Stiffeners Chosen (AD) by the span ("a"), by the number of sections ("s"), by the sum of (HSW plus BSF).

2. The total square feet of stiffeners for the module is summed immediately below the individual section computations.

AD8*A*S*(HSW+BSF)

AR: 1. This column calculates the weight of the stiffener used in the module. The value is obtained by multiplying the span ("a") by the number of sections ("s") by the sum of (HSW times TSW plus BSF times TSF), times the density of steel (0.283 pounds per cubic inch).

A*(HSW*TSW + BSF*TSF)*AD8*0.283

The total stiffener weight is summed immediately below the individual section computations.

AS: 1. This column displays the height of the frame web (HFW) to be used to compute the cost of the module using the modified procedure outlined in NSRP 0405.

2. This data is automatically copied into this column after the data (un-modified baseline ASSET data, or final structural shape data selected after satisfying MAESTRO Limit States) is parsed into the spreadsheet.

AT: This column displays the thickness of the frame web (TFW) to be used to compute the cost of the module using the modified procedure outlined in NSRP 0405. Similar to HFW data, the data is automatically copied into this column.

AU: This column displays the breadth of the frame flange (BFF) to be used to compute the cost of the module using the modified procedure outlined in NSRP 0405. Similar to HFW data, the data is automatically copied into this column.

AV: This column displays the thickness of the frame flange (TFF) to be used to compute the cost of the module using the modified procedure outlined in NSRP 0405. Similar to HFW data, the data is automatically copied into this column.

AW: 1. This column repeats the HFW reported or chosen in column AS. Care should be taken when describing what frames to export to/from MAESTRO.

2. This column identifies the HFW to be exported into the MAESTRO ".dat" file.

AX: 1. This column repeats the TFW reported or chosen in column AT. Care should be taken when describing what frames to export to/from MAESTRO.

2. This column identifies the TFW to be exported into the MAESTRO ".dat" file.

AY: 1. This column repeats the BFF reported or chosen in column AU. Care should be taken when describing what frames to export to/from MAESTRO.

2. This column identifies the BFF to be exported into the MAESTRO ".dat" file.

AZ: 1. This column repeats the TFF reported or chosen in column AV. Care should be taken when describing what frames to export to/from MAESTRO.

2. This column identifies the TFF to be exported into the MAESTRO ".dat" file.

BA: This column supplies an "!" required in MAESTRO to facilitate adding text to the end (right hand side) of data.

BB: This column provides a location for the user to identify the abbreviation of the frame shape used to create the dimensions of the structural member of concern.

BC: This column copies the structural description found in column AK. It is copied from the spreadsheet into the MAESTRO ".dat" file, and its presence in the ".dat" file facilitates easy editing.

BD: 1. This column is where the frame material is displayed or designated using the numeric identifiers provided starting in column AH1. Data is displayed or designated in this column in a fashion similar to the stiffener data found in column AO.

2. For un-modified baseline determinations, the value displayed is the numeric identifier the user added to the frame data while the data was yet in a sophisticated text editor. Once the

ASSET data is parsed into the spreadsheet, the material selection is automatically copied into this column.

3. For modified baseline and variant determinations, the frame material selection is input into this column.

BE: 1. This column calculates the linear feet of frame used in the module. The value is obtained by multiplying the Node Length (O8) of the structural member of concern by the number of longitudinal sections ("s") in the module.

$$08*S$$

2. The total frame linear feet is summed immediately below the individual section computations.

BF: 1. This column calculates the square feet of frame used in the module. The value is obtained by multiplying the Node Length (O8) of the structural member of concern by the number of sections ("s"), by the sum of (HFW plus BFF).

$$O8*S*(HFW + BFF)$$

2. The total frame square feet is summed immediately below the individual section computations.

BG: 1. This column calculates the weight of the frames used in the module. The value is obtained by multiplying the Node Length (O8) by the number of sections ("s") by the sum of (HFW times TFW plus BFF times TFF), times the density of steel (0.283 pounds per cubic inch).

$$O8*S*(HFW*TFW + BFF*TFF)*0.283$$

2. The total frame weight is summed immediately below the individual section computations.

BH: 1. This column is where the plate material is displayed or designated in a fashion similar to the stiffener material (column AO) and frame material (column BD).

BI: 1. This column designates the plate edge length. This length is the Node Length, and the value is copied from column O8 into this column.

BJ: 1. This column designates the number of edges which require some form of welding operation which occur along the length of the node (i.e. in the transverse direction). This value is required in order to determine the cost of the module using the modified NSRP 0405 spreadsheet, yet it is not determined by ASSET, nor is it otherwise known. The decision as to where to place plates to form a plate blanket must be determined by experience, reference to Detail Design or Production drawings or from another source. For this thesis, the DDG-51 Detail Design Drawings available at the MIT 13A office were used.

BK: 1. This column designates the Assembly orientation required by the structural member of concern. At present, the spreadsheet is not mature enough to differentiate between orientations, nor to weight operations differently based on orientation. The RANGE "orientation" is labeled in this column.

BL: 1. This column designates the Erection orientation required by the structural member of concern. The erection orientation is used to determine the edge preparation length of column CA. The Numeric value for FLAT ORIENTATION is assigned as one (1) in this column.

BM: 1. This column designates the shape of the structural member of concern.

2. The structural shape (designated as RANGE "shape") is labeled in this column. The RANGE "SHAPE" is labeled in this column. The Numeric value for VERTICAL ORIENTATION is assigned as two (2) in this column.

BN: 1. This column calculates the linear feet of plate used in the module. The value is obtained by multiplying the Number of Edges (BJ8) of the structural member of concern, by the span ("a"), by the number of longitudinal sections ("s") in the module.

BJ8*A*S

2. The Numeric value for a FLAT SHAPE is assigned as one (1) in this column. The Numeric value for OVERHEAD ORIENTATION is assigned as three (3) in this column.

3. The total linear feet of plate is summed immediately below the individual section computations.

BO: 1. This column calculates the square feet of plate used in the module. The value is obtained by multiplying the Node Length (O8) of the structural member of concern, by the span ("a"), by the number of sections ("s").

O8*A*S

2. The Numeric value for CURVED SHAPE is assigned as two (2) in this column.

3. The total square feet of plate is summed immediately below the individual section computations.

BP: 1. This column calculates the weight of the plates used in the module. The value is obtained by multiplying the square feet of plate (BO8) by the plate thickness (AF8) times the density of steel (0.283 pounds per cubic inch).

BO8*AF8*0.283

2. The total weight of plate is summed immediately below the individual section computations.

BQ: This column calculates the total square feet of structural material processed through the Material Receipt and Preparation (Mat'l Rec & Prep) process which are ultimately used to construct this module.

1. The value is the sum of the 2 times the number of edges and the plate linear feet, plus the frame linear feet plus the stiffener linear feet plus, if the orientation is flat, the number of stiffeners times the sum of (HSW + BSF) plus the number of frames times the sum of (HFW+BFF).

2*(BN12+BI12) + AP12+BE12
+@IF(BL12=1,(AN12*(AG12+AI12)+$S*(AS12+AU12))/12,0)

2. Range "NUM" is described at the top of this column. "NUM" is the sum of the different types of stiffener, frame, girder sizes and the different plate materials and thicknesses.

BR: This column reports the multiplier associated with Mat'l Rec & Prep. Additionally, the numerical values for the different types of stiffener, frame, girder sizes and the different plate materials and thicknesses defined here by the user.

BS: 1. This column calculates the man-hours associated with Mat'l Rec & Prep.

2. The man-hours are strictly based on square feet of structural material handled; a conversion factor of 0.01 man-hours per square foot times (0.35+0.65*NUM/30). See column BR for description of Range NUM.

3. The value is obtained by multiplying the Mat'l Rec & Prep square footage by the Mat'l Rec & Prep multiplier, and by the conversion factor.

4. The total man-hours for this column are summed immediately below the individual section computations.

BT: 1. This column reports the linear feet of Automatic Flame Cutting conducted associated with the structural member of concern. The spreadsheet uses the plate linear feet, determined in column BN, as the length which requires cutting.

2. If the plate is designated to be cut by automatic techniques, as reported in cell BU12, this column reports the linear feet of plate as found in column BN; otherwise a zero entry is provided in the cell.

BU: This column designates whether the plate associated with the structural member of concern is to be cut by automatic methods. For structural plate materials, shapes and thickness which are likely to be used in Naval Warship construction, it is difficult to conceive of conditions where automatic plate cutting methods would not be applicable, although it is quite reasonable to expect the preferred technique will not always be flame cutting.

BV: 1. This column reports the Stage at which the automatic flame cutting is to take place.

2. The stage is represented numerically as one of the following values: (1) FABRICATION, (2) PREOUTFITTING HOT, (3) PAINT, (4) PREOUTFITTING COLD, (5) ERECTION, (6) OUTFITTING, (7) WATERBORNE, (8) TEST AND TRIALS.

3. At present, the spreadsheet is not mature enough to differentiate between fabrication techniques completed at the different stages.

BW: 1. This column calculates the man-hours associated with automatic flame cutting. The computation requires the use of a "Look-up" Table. There are two (2) HTS Look-up tables within the spreadsheet: A_ORIGINAL and B_ORIGINAL. In this case, A_ORIGINAL Look-up table is used.

2. The A_ORIGINAL Look-up table is provided within the current spreadsheet. The table is a matrix. The rows display the entering argument for the table, this argument is the plate thickness or girder web thickness. The columns display unique factors associated with a single process or operation, such as edge preparation, or manual fillet welding.

3. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for automatic flame cutting, found in column 1 of the HTS Look-up table. The factor so found is multiplied by the Auto Flame Cut value reported in column BW.

4. The total man-hours for this column are summed immediately below the individual section computations.

BX: 1. This column calculates the length of material which requires manual flame cutting.

2. The spreadsheet determines the length which requires cutting by summing the plate linear feet which was not automatically cut, plus the number of stiffeners times[41] the sum of HSW plus BSF, plus the number of sections ("s") times the sum of HFW plus BFF, plus two times the node length (which accounts for the transverse length of the plates). BY: 1. This column reports the Stage at which the manual flame cutting is to take place.

2. The stage is represented numerically as one of those described for column BV.

3. At present, the spreadsheet is not mature enough to differentiate between fabrication techniques completed at the different stages.

BZ: 1. This column calculates the man-hours associated with manual flame cutting. The computation requires the use of column 2 of the A_ORIGINAL "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

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[41] If "I/Ts" are used, another length of stiffener is added.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for manual flame cutting. The factor so found is multiplied by the length requiring Manual Flame Cut (column BX) times the Stage factor (column BY).

3. The total man-hours for this column are summed immediately below the individual section computations.

CA: 1. This column calculates the length of material which requires edge preparation in a flat orientation.

2. The spreadsheet determines the length which requires flat edge preparation. This is accomplished by summing the following:

a. The total plate edge length. This is determined as twice plate linear feet, plus twice the node length.

b. The total length of plate surface from which primer removal is required. This is determined by summing the stiffener linear feet, plus the frame linear feet.

c. The total stiffener edge length (which is determined as, for "flat" assembly orientations (column BL), the number of stiffeners times the sum of HSW plus BSF); zero stiffener length for other assembly orientations.

d. The total frame edge length (which is determined as, for "flat" assembly orientations (column BL), the number of sections ("s") times the sum of HFW plus BFF); zero frame length for other assembly orientations.

CB: 1. This column reports the Stage at which the flat edge preparation is to take place.

2. The stage is represented numerically as one of those described for column BV.

3. At present, the spreadsheet is not mature enough to differentiate between fabrication techniques completed at the different stages.

CC: 1. This column calculates the man-hours associated with flat edge preparation. The computation requires the use of column 3 of the A_ORIGINAL "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for flat edge preparation. The factor so found is multiplied by the length requiring flat edge preparation (column CA) times the Stage factor (column CB).

3. The total man-hours for this column are summed immediately below the individual section computations.

CD: 1. This column calculates the length of material which requires edge preparation in a vertical orientation.

2. The spreadsheet determines the length which requires vertical edge preparation by summing the following:

a. The total stiffener edge length. This is determined as, for "vertical" assembly orientations (column BL), the number of stiffeners times the sum of HSW plus BSF); zero stiffener length for other assembly orientations.

b. The total frame edge length. This is determined as, for "vertical" assembly orientations (column BL), the number of sections ("s") times the sum of HFW plus BFF); zero frame length for other assembly orientations.

c. If the structural shapes are "I-T" (de-flanged), then add stiffener linear feet plus frame linear feet, add 0 if "IT" (split) are used.

CE: 1. This column reports the Stage at which the vertical edge preparation is to take place.

2. The stage is represented numerically as one of those described for column BV.

3. At present, the spreadsheet is not mature enough to differentiate between fabrication techniques completed at the different stages.

CF: 1. This column calculates the man-hours associated with vertical edge preparation. The computation requires the use of column 4 of the A_ORIGINAL "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for vertical edge preparation. The factor so found is multiplied by the length requiring vertical edge preparation (column CD) times the Stage factor (column CE).

3. The total man-hours for this column are summed immediately below the individual section computations.

CG: 1. This column calculates the length of material which requires edge preparation in an overhead orientation.

2. The spreadsheet determines the length which requires overhead edge preparation by summing the following:

a. The total stiffener edge length. This is determined as, for "overhead" assembly orientations (column BL), the number of stiffeners times the sum of HSW plus BSF); zero stiffener length for other assembly orientations.

b. The total frame edge length. This is determined as, for "overhead" assembly orientations (column BL), the number of sections ("s") times the sum of HFW plus BFF); zero frame length for other assembly orientations.

CH: 1. This column reports the Stage at which the overhead edge preparation is to take place.

2. The stage is represented numerically as one of those described for column BV.

3. At present, the spreadsheet is not mature enough to differentiate between fabrication techniques completed at the different stages.

CI: 1. This column calculates the man-hours associated with overhead edge preparation. The computation requires the use of column 5 of the A_ORIGINAL "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for overhead edge preparation. The factor so found is multiplied by the length requiring overhead edge preparation (column CF) times the Stage factor (column CG).

3. The total man-hours for this column are summed immediately below the individual section computations.

CJ: 1. This column calculates the number of structural shapes which are required to be rolled to achieve the desired shape by summing the following:

a. For these determinations, the number of rolled stiffeners is assumed to be all stiffeners for each panel as determined under the following conditions:

a.1. For un-modified and modified baseline determinations, the ASSET HULL STRUCTURES reports indicate which stiffeners were rolled by placing an "*R" adjacent to the stiffener dimensions. Using the "*R" in an "if" statement distinguishes among the rolled or flat plates and structural shapes. Therefore, the number of ASSET rolled stiffeners is summed with the values determined in sub-paragraphs CJ1.b. and CJ1.c. below.

a.2. For variant determinations, the designs of which will largely attempt to avoid rolling, the spreadsheet uses the user-defined "Shape" found in column BM . Therefore, for variant determinations, if the Shape is curved, the number of rolled stiffeners is assumed to all stiffeners associated with the panel.

b. The total number of frames which are rolled are determined in a fashion similar to that described in sub-paragraph CJ1.a..

c. If either the stiffeners or the frames are determined to be curved, the plate is assumed to be curved. Therefore, a value of one (1) is added to the sum of sub-paragraphs CJ1.a. and CJ1.b..

2. The total man-hours for this column are summed immediately below the individual section computations.

CK: 1. This column calculates the man-hours associated with creating the rolled shapes. While the use of a second look-up table, B_ORIGINAL Look-up table, is somewhat similar to that described for automatic flame cutting, the details warrant further description.

2. For stiffeners and frames, the man-hours are determined by summing the following:

a. If stiffeners are rolled, the TSW is used as the entering argument to column 7 of the B_ORIGINAL Look-up table, and the appropriate factor for "Shape-Roll" is retrieved. This factor is multiplied by the number of stiffeners.

b. If frames are rolled, the TFW is used as the entering argument to column 7 of the HTS Look-up table, and the appropriate factor for "Shape-Roll" is retrieved. This factor is multiplied by the number of sections ("s").

c. If either stiffeners or frames are rolled, the associated plate is presumed to require rolling. The plate thickness is used as the entering argument to column 7 of the HTS Look-up table, and the appropriate factor for "Shape-Roll" is retrieved. This factor is multiplied by the number of sections ("s").

3. The total man-hours for this column are summed immediately below the individual section computations.

CL: 1. This column calculates the number of shapes which are required to be line heated to achieve the desired shape.

2. If the shape column (BM) is designated "curved", then the number of shapes is the sum of the following:

a. The number of edges (column BJ) in the panel.

b. The number of sections in the panel.

c. The number of stiffeners in the panel.

CM: 1. This column calculates the man-hours associated with line heating the shapes. The number of shapes (column CM) which required line heating are multiplied by 1 man-hours per shape.

2. The total man-hours for this column are summed immediately below the individual section computations.

CN: 1. This column is used to determine the length (in feet) of all edges which require fitup and assembly. The value is the sum of the following:

a. one minus the number of sections times the node length;
b. the number of section ("s") times the length of each section ("a");

c. the stiffener linear feet;

d. the frame linear feet;

e. the number of stiffeners times the sum of HSW plus BSF;

f. half the number of sections times the sum of HFW plus BFF.

CO: 1. This column reports the Stage at which the fit-up and assembly is conducted.

2. The stage is represented numerically as one of those described for column BV.

3. At present, the spreadsheet is not mature enough to differentiate between fabrication techniques completed at the different stages.

CP: 1. This column reports the man-hours associated with the fit-up and assembly. The computation requires the use of column 6 of the A_ORIGINAL "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for overhead edge preparation. The factor so found is multiplied by the fit-up and assembly value (column CP).

3. The total man-hours for this column are summed immediately below the individual section computations.

CQ: 1. This column determines the plate square footage available to be distorted during fabrication. For those shapes, such as girders, which have no plates, a value of zero (0) is provided through the use of an "IF" statement.

CR: 1. This column determines the extent of distortion using an empirical formula, with the only independent variable being plate thickness. The formula was determined based on expert opinion from shipyard professional straighteners. The formula finds the exponential of the product of negative fifteen (-15) times the square of the plate thickness.

CS: 1. This column determines the labor man-hours per foot of plate, as a function of the plate thickness. The computation requires the use of column 3 of the HTS-C "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

CT: 1. This column determines the total labor man-hours associated with correcting, and as a result of, the distortion.

2. This value is computed as the product of the following: the plate square footage available for distortion (column CQ) times the amount of distortion (column CS) times the Increase Factor (which equals 6.5) divided by the value in Range "RATE".

3. The total man-hours for this column are summed immediately below the individual section computations.

CU: 1. This column calculates the length of automatic fillet weld conducted per section. This value is determined using an "IF" statement, returning two (2) times the sum of the stiffener linear feet plus the frame linear feet if the "Shape" (column BM) is designated as flat; zero (0) otherwise.

CV: 1. This column calculates the man-hours associated with automatic fillet welding. The computation requires the use of column 7 of the A_ORIGINAL "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for the automatic fillet weld. The factor so found is multiplied by the length requiring automatic fillet welding (column CU).

3. The total man-hours for this column are summed immediately below the individual section computations.

CW: 1. This column calculates the length of automatic butt weld conducted per section. This value is determined using an "IF" statement, returning two (2) times the plate linear feet if the "Shape" (column BM) is designated as flat; zero (0) otherwise.

CX: 1. This column calculates the man-hours associated with automatic butt welding. The computation requires the use of column 8 of the A_ORIGINAL "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for the automatic butt weld. The factor so found is multiplied by the length requiring automatic butt welding (column CW).

3. The total man-hours for this column are summed immediately below the individual section computations.

CY: 1. This column calculates the length of manual, down hand fillet weld conducted per section. This value is determined using an "IF" statement, returning two (2) times the sum of the stiffener linear feet plus the frame linear feet if the "Shape" (column BM) is designated as curved; zero (0) otherwise.

CZ: 1. This column calculates the man-hours associated with manual, down hand fillet welding. The computation requires the use of column 1 of the HTS-B "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for the manual, down hand fillet weld. The factor so found is multiplied by the length determined in column CY.

3. The total man-hours for this column are summed immediately below the individual section computations.

DA: 1. This column calculates the length of manual, down hand butt weld conducted per section. This value is determined using two IF" statements. This value is the sum of the following:

a. If the "Shape" (column BM) is curved, then two (2) times the plate linear feet; zero otherwise.

b. If the "Orientation" is flat (column BL), then two (2) times the sum of the following:

b.1. The node length.

b.2. The number of sections ("s") times the number of stiffeners times the sum of HSW plus BSF.

b.3. The number of sections ("s") times the sum of HFW plus BFF.

b.4. Zero (0) otherwise.

DB: 1. This column calculates the man-hours associated with manual, down hand butt welding. The computation requires the use of column 4 of the HTS-B "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for the manual, down hand butt weld. The factor so found is multiplied by the length determined in column DA.

3. The total man-hours for this column are summed immediately below the individual section computations.

DC: 1. This column calculates the length of manual, vertical butt weld conducted per section. This value is determined using two, nested "IF" statements. This value is the sum of the following:

a. If the "Shape" (column BM) is curved, then sum the following, zero otherwise:

b. If the "Orientation" is vertical (column BL), then two (2) times the sum of the following, zero otherwise:

b.1. The node length.

b.2. The number of sections ("s") times the number of stiffeners times the sum of HSW plus BSF.

b.3. The number of sections ("s") times the sum of HFW plus BFF.

DD: 1. This column calculates the man-hours associated with manual, vertical butt welding. The computation requires the use of column 5 of the HTS-B "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for the manual, vertical butt weld. The factor so found is multiplied by the length determined in column DE.

3. The total man-hours for this column are summed immediately below the individual section computations.

DE: 1. This column calculates the length of manual, overhead butt weld conducted per section. This value is determined using two, nested "IF" statements. This value is the sum of the following:

a. If the "Shape" (column BM) is curved, then sum the following, zero otherwise;

b. If the "Orientation" is overhead (column BL), then two (2) times the sum of the following, zero otherwise;

b.1. The node length.

b.2. The number of sections ("s") times the number of stiffeners times the sum of HSW plus BSF.

b.3. The number of sections ("s") times the sum of HFW plus BFF.

DF: 1. This column calculates the man-hours associated with manual, overhead butt welding. The computation requires the use of column 6 of the HTS-B "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. The plate thickness (column AF) or girder web thickness (column AH) is used to retrieve the appropriate factor for the manual, overhead butt weld. The factor so found is multiplied by the length determined in column DE.

3. The total man-hours for this column are summed immediately below the individual section computations.

DG: 1. This column calculates the number of pieces which require marking. The value is determined by adding the number of stiffener, the number of edges and twice the number of sections.

DH: 1. This column calculates the number of man-hours associated with marking. The computation requires multiplying the number of pieces (column DI) to be marked by 0.1 man-hours per piece times the sum of (0.85+0.15*NUM/30). See column BR for description of "NUM".

2. The total man-hours for this column are summed immediately below the individual section computations.

DI: 1. This column calculates the number of pieces which are required to be stored. This column presumes that, although Just-In-Time delivery practices may be used within the fabrication scheme, that there remains some storage of pieces. The value is determined by adding the number of stiffener, the number of edges and twice the number of sections.

DJ: 1. This column calculates the number of man-hours associated with storage. The computation requires multiplying the number of pieces (column DK) to be stored by 0.1 man-hours per piece times the sum of (0.5+0.5*NUM/30). See column BR for description of "NUM".

2. The total man-hours for this column are summed immediately below the individual section computations.

DK: 1. This column calculates the number of pieces which require transport throughout the facility. The value is determined by adding the number of stiffener, the number of edges and twice the number of sections.

DL: 1. This column calculates the number of man-hours associated with transportation. The computation requires multiplying the number of pieces (column DM) to be transported by 0.5 man-hours per piece times the sum of (0.65+0.35*NUM/30). See column BR for description of "NUM".

2. The total man-hours for this column are summed immediately below the individual section computations.

DM: 1. This column calculates the number of pieces which require lifting during fabrication. The value is determined by adding the number of stiffener, the number of edges and twice the number of sections.

DN: 1. This column calculates the number of man-hours associated with lifting. The computation requires multiplying the number of pieces (column DO) to be lifted by 0.5 man-hours per piece times the sum of (0.85+0.15*NUM/30). See column BR for description of "NUM".

2. The total man-hours for this column are summed immediately below the individual section computations.

DO: 1. This column calculates the total part square footage which requires blasting in preparation for priming. This value is determined by twice the sum of the stiffener square feet, plus the frame square feet, plus the plate square feet.

DP: 1. This column calculates the number of man-hours associated with blasting. The computation requires multiplying the total part square footage (column DQ) by 0.033 man-hours per foot times the sum of (0.85+0.15*NUM/30). See column BR for description of "NUM".

2. The total man-hours for this column are summed immediately below the individual section computations.

DQ: 1. This column calculates the total square footage which requires coating. This value is determined by twice the sum of the stiffener square feet, plus the frame square feet, plus the plate square feet.

DR: 1. This column calculates the number of man-hours associated with coating. The computation requires multiplying the total part square footage (column DS) by 0.033 man-hours per foot times the sum of (0.85+0.15*NUM/30). See column BR for description of "NUM".

2. The total man-hours for this column are summed immediately below the individual section computations.

DS: 1. This column calculates the total number of direct man-hours consumed per section for structural shapes for all activities listed above.

2. The total man-hours for this column are summed immediately below the individual section computations.

DT: 1. This column calculates the total number of support man-hours consumed per section for structural shapes which are associated with the activities listed above.

2. It is presumed that there are 0.25 man-hours of support labor for every one (1) hour of direct labor. Therefore, the value reported in this column is the total direct labor hours (column DU) multiplied by 0.25.

3. The total man-hours for this column are summed immediately below the individual section computations.

DU: 1. This column calculates the total labor (direct and support) associated with the scantling activities listed above. This computations is the sum of the total direct (column DU) and the total support (column DV) man-hours.

2. The total man-hours for this column are summed immediately below the individual section computations.

3. This column labels the stiffener shape selection of "IT" or "I-T".

DV: This column calculates the total structural shape cost for labor associated with this section. This computation is the "RATE" (cell DW6) multiplied by the total labor hours.

DW: 1. This column calculate the plate, and floors or brackets, material cost for the section. The plate "Look-up" table is based on actual plate cost information obtained from Bath Iron Works. The computation requires the use of column 1 of the HTS-D "Look-up" Table. This is done in a fashion similar to that described for automatic flame cutting.

2. Cell 4 of this column is where "YES" is placed in answer to the stiffener shape question of column DU.

DX: This column calculates the total stiffener and girder cross-section area for the section.

DY: This column calculates the total frame cross-section area for the section.

DZ: This column is the stiffener and girder cost for the section. The value is computed by an empirical formula which differentiates between "I-T" (de-flanged) an "IT" (split) beams. The basis for the empirical formula is discussed in Chapter 5.

EA: This column is the frame cost for the section. The value is computed by an empirical formula which differentiates between "I-T" (de-flanged) an "IT" (split) beams. The basis for the empirical formula is discussed in Chapter 5.

EB: This column sums the structural shape material costs, which are found in columns DV, DZ and EA.

EC: This column sums the total structural shape cost, material and labor, which is found in columns DV and EB.

ED: This column reports the total tube man-hours, direct and indirect, which is calculated in the "TUBE" range.

EE: This column reports the total tube labor cost, which is calculated in the "TUBE" range.

EF: This column reports the total tube material cost, which is calculated in the "TUBE" range.

EG: This column reports the total tube cost, labor and material, which is calculated in the "TUBE" range.

EH: This column reports the scantling (plate, stiffeners, girders, frames and floors) weight for both halves of the module.
EI: This column reports the total tube weight for both halves of the module, which is calculated in the "TUBE" range.

EJ: This column reports the total module (structural shape and tube) for both halves.

EK: This column reports the total module weight as determined by MAESTRO.

Appendix 7 Description of Pillar Portion of Modified Spreadsheet

Pillar or "TUBE" calculations:

The Range which determines the various values for the pillars is found beginning at cell A65

A: All pillars are assumed to be located on every other frame (MAESTRO Section 0, 2 and 4)

B: 1. The pillar material is assumed to be schedule 80 material

2. The tube material is labeled as 1 (mild steel), 2 (HTS) or 3 (HY-80).

C: The wall thickness for each tube is reported here. This is not an ASSET value. DDG-51 Detail Design drawing indicates 0.365 inch.

D: The outer tube diameter is reported here. This is not an ASSET value. DDG-51 Detail Design drawing indicates 10.75 inch.

E: This column reports a MAESTRO place holder.

F: This column reports a MAESTRO place holder.

G: This column reports the effective length factor required by MAESTRO. See MAESTRO user manual.

H: This column reports the number of sections in the module which have tubes.

I: This column calculates the number of tube pieces which require Material Receipt and Preparation.

J: This column reports the multiplication factor for Material Receipt and Preparation.

K: This column reports the man-hours for Material Receipt and Preparation.

L: This column reports whether the tube is machine or manually cut. For this thesis, all tube are considered to be machine cut.

M: This column reports the man-hours for Machine Cutting.

N: This column reports the man-hours for Manually Cutting.

O: This column reports the number of bends in the tube. For this thesis, no bends were considered.

P: This column reports the type of bend (angle or 3-D). For this thesis, no bends were considered.

Q: This column calculates the man-hours for machine bending.

R: This column calculates the man-hours for manual bending.

S: This column calculates the man-hours for marking, identical to structural shape marking.

T: This column calculates the man-hours for storage, identical to structural shape marking.

U: This column calculates the man-hours for transporting, identical to structural shape marking.

V: This column calculates the man-hours for lifting, identical to structural shape marking.

W: This column reports the number of joints which require welding. For this thesis, either end, or 2 joints are used.

X: This column calculates the man-hours required for socket welding the joints. "Lookup-pipe-b" table, column 5 is used. The column number is identified as the numeric value reported in cell X69, see NSRP 0405 for further details.

Y: This column calculates the man-hours required for fitup and assembly. "Lookup-pipe-a" table, column 4 is used. The value determined by the lookup table is divided by 10 to force this fitup man-hours to comply with those determined by structural shape fitup.

Z: This column reports the distance between decks used for the pillars.

AA: This column calculates the exterior surface preparation man-hours, identical to structural shape calculations.

AB: This column calculates the interior surface preparation man-hours, the man-hours are considered to be twice those required for exterior surface preparation.

AC: This column calculates the interior surface coating man-hours, identical to structural shape calculations.

AD: This column sums the direct man-hours for this set of tubes.

AE: This column sums the indirect man-hours for this set of tubes, using a 25% support factor.

AF: This column sums the total labor hours.

AG: This column determines the labor cost, using the Range "RATE" and the column AF.

AH: This column determines the material cost by considering tube costs are $0.40/lb.

AI: This column determines the tube weight.

Appendix 8 Description of Edges in Modified Spreadsheet

EDGES: All plates modeled by ASSET and in MAESTRO having an node at the centerline are considered to be continuous across the centerline. These plates have only one edge.

The Detail Design Drawing of the DDG-51 is used as guide for placing the remaining plate edges. The symbol "$" is used on the DDG-51 drawing to indicate butt welds between plates. The basic location of the DDG-51 butt welds was retained in all designs considered in this thesis.

The edge selection of the 4-deck midsection, shown in the following figure, are described below.

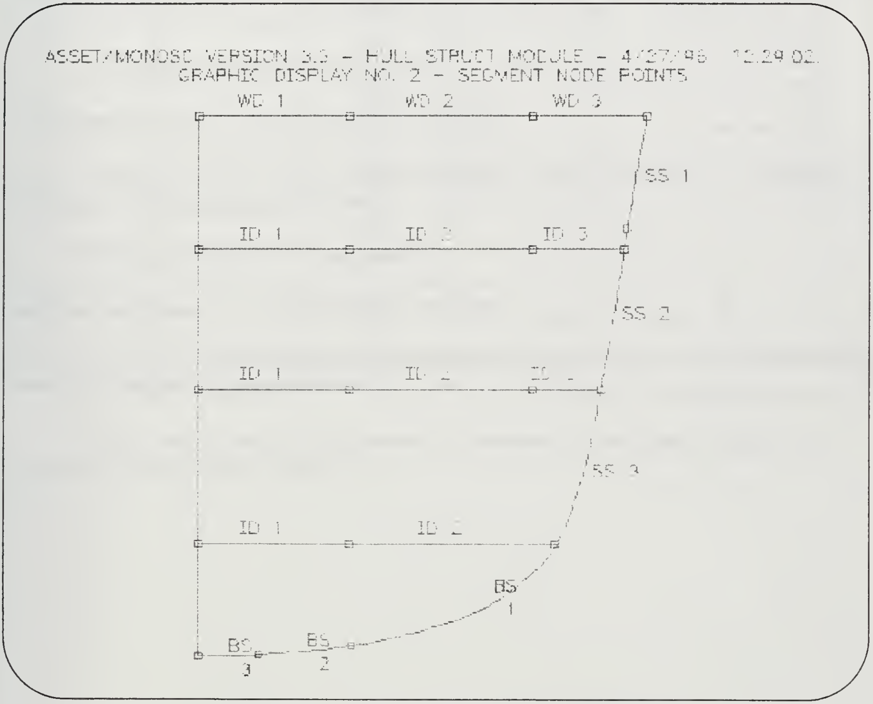


Figure 8a-1 ASSET Midship Section for DDG-51

The following table provides a description of "EDGE" Selection for Modeling in MAESTRO.

Table 8a-1 Description of Edges for DDG-51

Plate	# Edges	Edge Nodes	Plate	# Edges	Edge Nodes
!WD1	0	1-2	!IB1	1	10-15
!WD2	1	2-3	!IB2	1	15-16
!WD3	1	3-4	!IB3	1	16-17
!SS1	2	4-5	!IB4	0	17-18
!SS2	0	5-6	!IB5	0	18-19
!SS3	1	6-7	!ID1-1	0	20-21
!SS4	0	7-8	!ID1-2	1	21-22
!SS5	1	8-9	!ID2-1	0	23-24
!BS1	0	9-10	!ID2-2	1	24-25
!BS2	0	10-11	!ID2-3	2	25-7
!BS3	0	11-12	!ID3-1	0	26-27
!BS4	0	12-13	!ID3-2	2	27-8
!BS5	1	13-14	!ID4-1	0	28-29
			!ID4-2	2	29-9
			!F-4	2	19-14
			!F-3	2	18-13
			!F-2	2	17-12
			!F-1	2	16-11

Appendix 9a Weight, Vertical Bending Moment Description and FSC MAESTRO ".dat" file

FULL LOAD WEIGHT DISTRIBUTION:

The Full Load weight distribution was estimated as the full load weight minus the sum of the weight of SWBS Groups 110, 130 and 140. See Group XV of the attached MAESTRO "FSC.DAT" file.

VERTICAL BENDING MOMENT ESTIMATION:

The midship vertical bending moment was estimated using the DDG-51 Detail Design Moment Diagram, and an empirical vertical bending moment equation. The maximum DDG-51 Detail Design hog moment is -1.719e5 lton*ft, and the sag moment is 9.109e4 lton*ft.

The empirical equation for hog moment is:

Hog Bending Moment = (-4.57E-4)*(LBP^2.5)*BEAM

The DDG-51 hog bending moment determined by using this equation is: -1.264E5 lton*ft. The ratio of Detail-to-Empirical is 1.360.

The empirical equation for sag moment is:

Sag Bending Moment = (3.81E-4)*(LBP^2.5)*BEAM

The DDG-51 sag bending moment determined by using this equation is: 1.054E5 lton*ft. The ratio of Detail-to-Empirical is 0.864.

The FSC hog and sag bending moments are estimated by multiplying the empirically determined value by the appropriate ratio.

FSC Producible Design with Satisfactory Limit State Adequacy Parameter Values:

The following is the complete MAESTRO "Data" file.

```
"FSC.DAT - ASSET_FSC ship"
$DESIGN 3 0 0 0 0 0 0 1 1 0 0
ANALYSIS 1 1
2 2 1 1 , , , 1 1 , 1
UNITS pounds inches "K-DOLLARS" tons
CRITERIA DEFAULT 1.50 1.25
MATERIAL 1 29.6E+06 0.3 34000 50000 37000 .283 1.2634E-04
$!welding stress ratio 0.1 !Mild Steel
MATERIAL 2 29.6E+06 0.3 51000 70000 51000 .283 1.2634E-04
$!welding stess ratio 0.1 !HSS
MATERIAL 3 29.6E+06 0.3 80000 100000 80000 .283 1.2634E-04
$!welding stess ratio 0.1 !HY80
SUBS 1
0.0 0.0 0.0
MODULE 1
$ GROUP IA - BASIC MODULE PARAMETERS
4 24 , 0 0 , 0 , Y Y 1
$ GROUP IB - MODULE DEFAULT VALUES
96 0 0 0 56 0.56 !changed Be/t from infinite to 56
$ GROUP II - ENDPOINT LOCATIONS
$!Y-coordinate, Z-coordinate
462.00 0.00 ! 1
462.00 123.60 ! 2
462.00 272.04 ! 3
462.00 365.64 ! 4
348.00 346.92 ! 5
228.00 327.84 ! 6
96.00 291.00 ! 7
47.44 243.67 ! 8
9.60 125.04 ! 9
1.44 49.32 ! 10
0.00 0.00 ! 11
348.00 0.00 ! 12
348.00 123.60 ! 13
348.00 272.04 ! 14
228.00 0.00 ! 15
228.00 123.60 ! 16
228.00 272.04 ! 17
96.00 0.00 ! 18
96.00 123.60 ! 19
END
$ GROUP III - ADDITIONAL NODES
$ GROUP IVA - DEFINITION OF STRAKES
DECK 1 1 2 2 2 2 , L ,-T
DECK 2 2 3 2 2 2 , L ,-T
DECK 3 3 4 3 3 3 , L ,-T
SIDE 4 4 5 3 3 3 , L
SIDE 5 5 6 2 2 2 , L
SIDE 6 6 7 2 2 2 , L
BOTTOM 7 11 10 2 2 2 , L
BOTTOM 8 10 9 2 2 2 , L
BOTTOM 9 9 8 2 2 2 , L
BOTTOM 10 8 7 2 2 2 , L
OTHER 11 12 13 2 2 2 , L ,-T
OTHER 12 13 14 2 2 2 , L ,-T
OTHER 13 14 5 2 2 2 , L ,-T
OTHER 14 15 16 2 2 2 , L ,-T
OTHER 15 16 17 2 2 2 , L ,-T
OTHER 16 17 6 2 2 2 , L ,-T
OTHER 17 18 19 2 2 2 , L ,-T
OTHER 18 19 7 2 2 2 , L ,-T
END ! Terminates "Def. of Strakes"
```

FSC Producible Design with Satisfactory Limit State Adequacy Parameter Values:

```
$ GROUP IVB - LONGITUDINAL GIRDERS
GIRDER      1  1  2 , 180.! at centerline
      +   2  1  2 , 180.!
      +   7  7  2 ,
      +   8  7  2 ,
      +   9  8  2 ,
      +   10 9  2  ,
      +  11  11  2 , 180.! at centerline
      +  12  11  2 , 180.!
      +  14  14  2 , 180.! at centerline
      +  15  14  2 , 180.!
      +  17  17  2 , 180.! at centerline
      +  18  17  2 , 180.!
END
ENDSUP
$GROUP VI(A) - PILLAR
$!tube size determined from "Manual of Steel Const." AISC
$! "0.7" used to approx. pinned-clamped condition
STRUT 2
$from DDG-51 drwg
TUBE  01 0 12 0 2 0.237  4.50 , . 0.7
  + 02 0 13 0 2 0.237  4.50 , , 0.7
  + 12 0 15 0 2 0.237  4.50 , , 0.7
  + 13 0 16 0 2 0.237  4.50 , , 0.7
  + 15 0 18 0 2 0.237  4.50 , , 0.7
  + 16 0 19 0 2 0.237  4.50 , , 0.7
  + 18 0 11 0 2 0.237  4.50 , , 0.7
  + 19 0 9  0 2 0.237  4.50 , , 0.7
TUBE  01 2 12 2 2 0.237  4.50 , , 0.7
  + 02 2 13 2 2 0.237  4.50 , , 0.7
  + 12 2 15 2 2 0.237  4.50 , , 0.7
  + 13 2 16 2 2 0.237  4.50 , , 0.7
  + 15 2 18 2 2 0.237  4.50 , , 0.7
  + 16 2 19 2 2 0.237  4.50 , , 0.7
  + 18 2 11 2 2 0.237  4.50 , , 0.7
  + 19 2 9  2 2 0.237  4.50 , , 0.7
TUBE  01 4 12 4 2 0.237  4.50 , , 0.7
  + 02 4 13 4 2 0.237  4.50 , , 0.7
  + 12 4 15 4 2 0.237  4.50 , , 0.7
  + 13 4 16 4 2 0.237  4.50 , , 0.7
  + 15 4 18 4 2 0.237  4.50 , , 0.7
  + 16 4 19 4 2 0.237  4.50 , , 0.7
  + 18 4 11 4 2 0.237  4.50 , , 0.7
  + 19 4 9  4 2 0.237  4.50 , , 0.7
$GROUP VII(A) - ADDL. BEAMS
$GROUP VII(B) - ADDL. PANELS
$GROUP IX - PANEL SCANTLINGS
$!   t    HW    TW   BF  TF
4 0 0.4375 2.3625 0.25 4.02 0.395 ! WD1
5 0 0.4375 2.3625 0.25 4.02 0.395 ! WD2
3 0 0.4375 2.3625 0.25 4.02 0.395 ! WD3
5 0 0.4375 2.3625 0.25 4.02 0.395 ! SS1
4 0 0.4375 6.3574 0.49 9.99 0.745 ! SS3
5 0 0.4375 6.3574 0.49 9.99 0.745 ! SS4
1 0 0.5 7.845 0.605 11.535 0.96 ! BS1
3 0 0.4375 6.3574 0.49 9.99 0.745 ! BS2
4 0 0.4375 6.3574 0.49 9.99 0.745 ! BS3
2 0 0.4375 6.3574 0.49 9.99 0.745 ! BS4
4 0 0.3125 1.87 0.245 4.015 0.315 ! ID1-1
5 0 0.3125 1.87 0.245 4.015 0.315 ! ID1-2
2 0 0.3125 3.75 0.295 6.895 0.43 ! ID1-3
4 0 0.3125 1.87 0.245 4.015 0.315 ! ID2-1
5 0 0.3125 1.87 0.245 4.015 0.315 ! ID2-2
1 0 0.3125 1.87 0.245 4.015 0.315 ! ID2-3
4 0 0.3125 1.87 0.245 4.015 0.315 ! ID3-1
6 0 0.3125 1.87 0.245 4.015 0.315 ! ID3-2
```

FSC Producible Design with Satisfactory Limit State Adequacy Parameter Values (continued)

```
$GROUP X - GIRDER SCANTLINGS
$HGW   TGW   BGF   TGF
2.865  0.13  4.03  0.2125 !  G1 (half)
2.865  0.26  4.03  0.425 !  G2
5.64  0.22  8.99  0.34  !  B1
5.64  0.44  8.99  0.68  !  B2
5.64  0.44  8.99  0.68 !  B3
5.64  0.44  8.99  0.68 !  B4
2.865   0.13   4.03   0.2125 !  G12 (half)
2.865   0.26   4.03   0.425  !  G13
1.87   0.1225   4.015   0.1575 !  G15(half)
1.87   0.26   4.015   0.315  !  G16
1.87   0.1225   4.015   0.1575  !  G18(half)
1.87   0.26   4.015   0.315  !  G19
$GROUP XI - FRAME SCANTLINGS
$HSW   TSW   BSF   TSF
1.87 0.245 4.015 0.315  !   WD1
1.87 0.245 4.015 0.315  !   WD2
1.87 0.245 4.015 0.315  !   WD3
6.3575  0.49  9.99  0.745  !   SS1
6.3575  0.49  9.99  0.745   !   SS3
7.845  0.605  11.535  0.96   !   SS4
6.3575  0.49  9.99  0.745   ! bs1
8.4925  0.83  12.18  1.36   ! bs2
8.4925  0.83  12.18  1.36  ! bs3
8.4925  0.83  12.18  1.36  ! bs4
2.3625  0.25  4.02  0.395 !   ID1-1
2.3625  0.25  4.02  0.395 !   ID1-2
3.75  0.295  6.685  0.43 !   ID1-3
2.3625  0.25  4.02  0.395 !   ID2-1
2.3625  0.25  4.02  0.395 !   ID2-2
3.75  0.295  6.685  0.43 !   ID2-3
1.87  0.245  4.015  0.315   !   ID3-1
1.87  0.245  4.015  0.315   !   ID3-2
$GROUP XII(A) - ADDL. BEAM SCANTLINGS
$GROUP XII(B) - ADDL. PANEL SCANTLINGS
$GROUP XIII(B) - BRACKETS ON TRANSVERSE FRAMES
BRT 3  4 4 1 26. 30. .3125 4.02  0.395
+   13 5 5 1  16. 40. .3125 4.02  0.395
+   16 6 6 1  16. 40. .3125 4.02  0.395
$length of brackets chosen to mimic DDG-51
END
$GROUP XV - MODIFICATIONS TO THE STRUCTURAL MODEL
END
BOUND  1  1  1   1
RESTRAINT   1   1   4   4   110001
END
LOADSET 1 "STATICLOADS (STEEL,OUTFIT,MACH'Y,DECKHS,BOUYANCY)"
Y  1.0  1
IMMERSION  218.76
0  0  0  1.0
$$ENGINE AND MACHINERY WEIGHTS
$$SUPERSTRUCTURE LOAD
WEIGHT
$=Full load displacement - (GRP 110+130+140)
$NOTE: THESE WEIGHTS WILL BE UNIQUE FOR EACH BASE-VART
$=(6580.08-(517/4+465/1+41/3)) / (430*12) = 2413.34 #/in.
2412.34 2412.34 2412.34 2412.34
LOADSET 2  "HOGGING WAVE"
Y  1.0
IMMERSION  218.76  0.  0.  WAVEONLY  146.5  5160  000  0.
0 0 0 1.0
LOADSET 3  "SAGGING WAVE"
Y  1.0
IMMERSION  218.76  0.  0.  WAVEONLY  146.5   5160  180  0.
0 0 0 1.0
```

FSC Producible Design with Satisfactory Limit State Adequacy Parameter Values (continued):

```
LOADSET 4  "WEATHER DECK GREEN SEAS +  LIVE LOAD"
Y  1.0
0  3  0
DPRESS   1  2.9 !4ft head of SW + live load
DPRESS   2  2.9 !4ft head of SW + live load
DPRESS   3  2.9 !4ft head of SW + live load
LOADSET 5 "DAMAGE LOADS, FLOODING ID1 only"
Y  1.0
0  3  0
DPRESS  11 4 !head due to flooding
DPRESS  12 5 !head due to flooding
DPRESS  13 8 !head due to flooding
END
CASE 1 "STATIC LOADS + HOGGING WAVE"
1.0  1   2   4
-3.2226e9  -3.493e9   -1.4158e6  0
CASE 2 "STATIC LOADS + SAGGING WAVE"
1.0  1   3   4
1.7138e9  1.845e9 6.7989e5  0
CASE 3 "STATIC LOADS +HOG + DAMAGE"
1.0 1 2 4 5
-3.2226e9  -3.493e9   -1.4158e6  0
ENDLOADS
```

Appendix 9b ASSET As-Suggested Information

The ASSET as-suggested structural model uses 20 different "I-T's" for use. The ASSET suggested structural shapes are listed below:

Table 9b-1 ASSET As-Suggested Structural Shape Sizes

Number of Uses	Height Web	Thickness Web	Breadth Flange	Thickness Flange
2	3	0.13	2	0.19
6	3.75	0.17	3.94	0.21
4	3.92	0.12	2	0.18
3	4.92	0.12	3	0.18
1	5.69	0.17	1.97	0.43
1	5.73	0.24	4.01	0.35
3	5.99	0.18	5	0.31
2	6.95	0.18	2	0.25
3	6.99	0.18	3	0.31
1	7.74	0.23	4	0.26
5	7.8	0.25	4.02	0.32
1	8.93	0.25	3	0.37
1	9.72	0.23	4	0.27
3	9.78	0.24	4.01	0.33
1	11.73	0.22	3.99	0.27
1	11.89	0.26	4.03	0.43
1	13.41	0.23	5	0.34
1	13.49	0.26	5.03	0.42
1	15.35	0.25	5.5	0.35
1	17.38	0.32	6.02	0.53

ASSET As-Suggested scantlings: achieves un-satisfactory adequacy parameter values.

Tube size: Standard Strength Wall Thickness 0.365 inch, outer diameter 10.75.

```
$GROUP IX  PANEL SCANTLINGS
$!   t    HW   TW   BF    TF
4 0 0.375        3.92 0.12 2       0.18 ! WD1 From Asset
5 0 0.375        3.92 0.12 2       0.18 ! WD2 From Asset
3 0 0.3438       3.92 0.12 2       0.18 ! WD3 From Asset
4 0 0.3438       3.92 0.12 2       0.18 ! SS1 From Asset
0 0 0.3438       3.92 0.12 2       0.18 ! SS2 From Asset
4 0 0.3125       3.745 0.17 3.94   0.205 ! SS3 From Asset
5 0 0.3125       4.73 0.19 3.96    0.21 ! SS4 From Asset
1 0 0.4375       7.685 0.17 3.94   0.205 ! BS1 From Asset
6 0 0.4375       7.685 0.17 3.94   0.205 ! BS2 From Asset
1 0 0.4375       5.735 0.2 3.97    0.225 ! BS3 From Asset
4 0 0.25  3.745 0.17 3.94   0.205 ! ID11 From Asset
5 0 0.25  3.745 0.17 3.94   0.205 ! ID12 From Asset
2 0 0.3438       3.745 0.17 3.94   0.205 ! ID13 From Asset
4 0 0.25  3.745 0.17 3.94   0.205 ! ID21 From Asset
5 0 0.25  3.745 0.17 3.94   0.205 ! ID22 From Asset
1 0 0.3438       3.745 0.17 3.94   0.205 ! ID23 From Asset
4 0 0.25  3.745 0.17 3.94   0.205 ! ID31 From Asset
6 0 0.25  3.745 0.17 3.94   0.205 ! ID32 From Asset
$GROUP X  GIRDER SCANTLINGS
$HGW   TGW   BGF   TGF
6.99 0.09 1.5 0.31 ! G1 (half) From Asset
5.99 0.18 5 0.31 ! G2 From Asset
6.99 0.18 3 0.31 ! G3 From Asset
5.73 0.235 4.01 0.35 ! B11 From Asset
7.795 0.245 4.02 0.315 ! B12 From Asset
9.78 0.12 2.005 0.33 ! B13 From Asset
5.685 0.085 1.97 0.215 ! G12 (half) From Asset
7.735 0.23 4 0.255 ! G13 From Asset
7.795 0.245 4.02 0.315 ! G14 From Asset
7.795 0.1225 2.01 0.315 ! G15(half) From Asset
9.78 0.24 4.01 0.33 ! G16 From Asset
9.72 0.23 4 0.27 ! G17 From Asset
9.78 0.12 2.005 0.33 ! G18(half) From Asset
11.885 0.26 4.03 0.425 ! G19 From Asset

$GROUP XI  FRAME SCANTLINGS
$HSW   TSW   BSF   TSF
6.9900 0.1800 4.0000 0.3100 !  WD1
8.9300 0.2500 3.0000 0.3700 !  WD2
6.9500 0.1800 2.0000 0.2500 !  WD3
11.7250 0.2200 3.9900 0.2650 !  SS1
15.3450 0.2500 5.5000 0.3450 !  SS2
17.3750 0.3150 6.0200 0.5250 !  SS3
13.4900 0.2550 5.0300 0.4200 !  SS4
13.4050 0.2300 5.0000 0.3350 !  BS1
7.7950 0.2450 4.0200 0.3150 !  BS2
7.7950 0.2450 4.0200 0.3150 !  BS3
4.9200 0.1200 3.0000 0.1800 !  ID11
5.9900 0.1800 2.0000 0.3100 !  ID12
3.0020 0.1250 2.0000 0.1880 !  ID13
4.9200 0.1200 3.0000 0.1800 !  ID21
5.9900 0.1800 2.0000 0.3100 !  ID22
3.0020 0.1250 2.0000 0.1880 !  ID23
4.9200 0.1200 3.0000 0.1800 !  ID31
6.9500 0.1800 2.0000 0.2500 !  ID32
```

As-Suggested ASSET histogram

Table 9b-2 As-Suggested ASSET Model MAESTRO Historgram

HISTOGRAM OF ADEQUACY PARAMETER VALUES
****

0.95 TO 1.00	20
0.85 TO 0.95	81
0.75 TO 0.85	52
0.65 TO 0.75	56
0.55 TO 0.65	46
0.45 TO 0.55	70
0.35 TO 0.45	34
0.25 TO 0.35	51
0.15 TO 0.25	25
0.05 TO 0.15	25
0.01 TO 0.05	9
TRANSITION	
0.01 T0 0.01	0
UNSATISFIED	
0.05 TO 0.01	7
0.15 TO 0.05	9
0.25 TO 0.15	0
0.35 TO 0.25	10
0.45 TO 0.35	2
0.55 TO 0.45	3
0.65 TO 0.55	7
0.75 TO 0.65	1
0.85 TO 0.75	0
0.95 TO 0.85	3
1.00 TO 0.95	2

NULL (STRAKE NOT EVALUATED) 0

Appendix 9c "Adequate" Information for Traditional Design

The structural shapes which are required to satisfy the adequacy parameters for the ASSET structural model are listed below:

Table 9c-1 Satisfactory Structural Shape Sizes for ASSET Model

Number of Uses	Height Web	Thickness Web	Breadth Flange	Thickness Flange
1	3	0.13	2	0.19
10	3.75	0.17	3.94	0.21
3	4.92	0.12	3	0.18
1	5.69	0.17	1.97	0.43
3	5.99	0.18	5	0.31
1	6.95	0.18	2	0.25
1	6.99	0.18	3	0.31
1	7.74	0.23	4	0.26
4	7.8	0.25	4.02	0.32
1	8.93	0.25	3	0.37
1	9.72	0.23	4	0.27
2	9.78	0.24	4.01	0.33
4	9.81	0.24	5.75	0.36
3	11.73	0.22	3.99	0.27
1	11.89	0.26	4.03	0.43
2	13.41	0.23	5	0.34
2	15.44	0.28	5.53	0.44
7	17.38	0.32	6.02	0.53
3	20.38	0.4	8.24	0.62

There are six plate thicknesses which are used, listed below:

Table 9c-2 List of ASSET Plate Thicknesses for Satisfactory Adequacy Parameters

1/4"	0.25
5/16"	0.31
11/32"	0.34
3/8"	0.38
7/16"	0.44
9/16"	0.56

Appendix 9d

REDUCED "IT" CATALOGUE:

The reduced "IT" catalogue includes a reasonably reduced selection of structural shapes which might be required for FSC or for any other frigate/destroyer-sized naval vessel. Fourteen (14) "ITs" were selected from among the 193 listed in the MANUAL of STEEL CONSTRUCTION. The moment of inertia about the mid-web per pound per foot (I/#/ft) was determined. This location is chosen since it is where the "ITs" are split. There are obvious "knees" in the curve which are likely candidates for selection if the only criteria is a relative maximum "I/#/ft". However, the structural shapes included in the reduced catalogue are those which have the lowest perimeter corresponding to the structural shape which has the maximum "I/#/ft". In all cases, a lower numbered structural shape is chosen.

The following method is used to determine the "I".

I = (BF/12)*TF^3 + (TW/12)*HW^3 + BF*TF*(HW +TF/2)^2 + (TW/4)*HW^3
(where the first two terms determine the moment of inertia about the flange and split-web centroid (respectively), and the second two terms determine the contribution about the toe of the "T" through the parallel axis theorem).

Table 9d-1 presents the selected structural shape catalogue. Table 9d-1 presents a plot of the characteristics of all "ITs", while Figure 9d-1 presents a plot of the characteristics of all "I-Ts". and Figure 9d-2 presents a plot of the characteristics of all "ITs".

Table 9d-1 Selected Structural Shape Catalogue

WT - Split	Cat. #	*D*	*HSW*	*TW*	*BF*	*TF*	*A - Eff.*	*I*	*LB/FT*	*I/LB/FT*	*TF/TW*	*D/BF*	*AF/A*
WT18X105	8	18.35	8.49	0.83	12.18	1.36	23.61	1,565.69	80.29	19.5	1.64	1.51	0.7
WT16.5X70.5	22	16.65	7.85	0.61	11.54	0.96	15.82	865.68	53.79	16.09	1.59	1.44	0.7
WT15X62	31	15.09	7.08	0.59	10.52	0.93	13.92	626.15	47.33	13.23	1.59	1.44	0.7
WT13.5X47	43	13.46	6.36	0.49	9.99	0.75	10.56	379.41	35.9	10.57	1.52	1.35	0.71
WT12X38	54	11.96	5.64	0.44	8.99	0.68	8.6	245.16	29.22	8.39	1.55	1.33	0.71
WT10.5X28.5	69	10.53	4.94	0.41	6.56	0.65	6.26	134.53	21.29	6.32	1.61	1.61	0.68
WT9X35.5	79	9.23	4.21	0.5	7.64	0.81	8.27	144.53	28.12	5.14	1.64	1.21	0.75
WT8X18	95	7.93	3.75	0.3	6.99	0.43	4.11	52.45	13.97	3.75	1.46	1.14	0.73
WT7X13	119	7	3.29	0.26	5.03	0.42	2.95	28.87	10.03	2.88	1.65	1.39	0.72
WT6X11	140	6.16	2.87	0.26	4.03	0.43	2.46	18.29	8.36	2.19	1.64	1.53	0.7
WT5X9.5	158	5.12	2.36	0.25	4.02	0.4	2.18	11.53	7.41	1.56	1.58	1.27	0.73
WT4X7.5	172	4.06	1.87	0.25	4.02	0.32	1.72	5.74	5.86	0.98	1.29	1.01	0.73
WT3X8	178	3.14	1.37	0.26	4.03	0.41	1.99	4.27	6.76	0.63	1.56	0.78	0.82
WT2X6.5	183	2.08	0.87	0.28	4.06	0.35	1.64	1.59	5.59	0.28	1.23	0.51	0.85

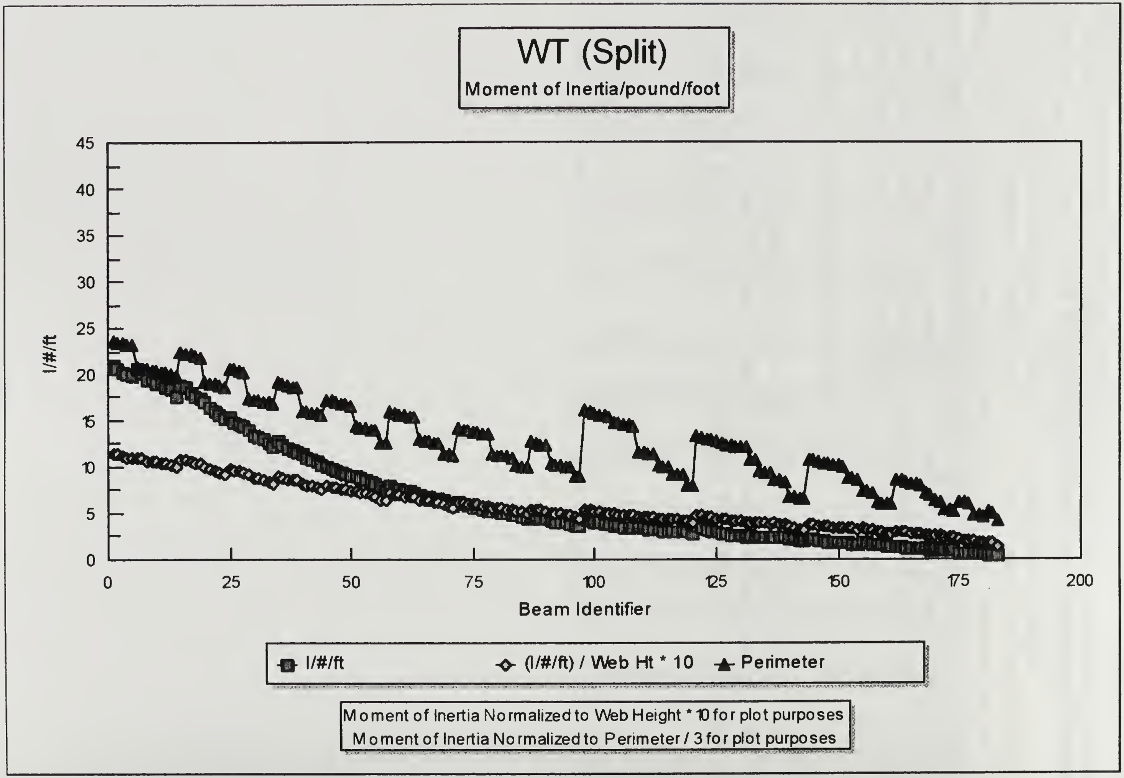


Figure 9d-1 "IT" Beam Characteristics

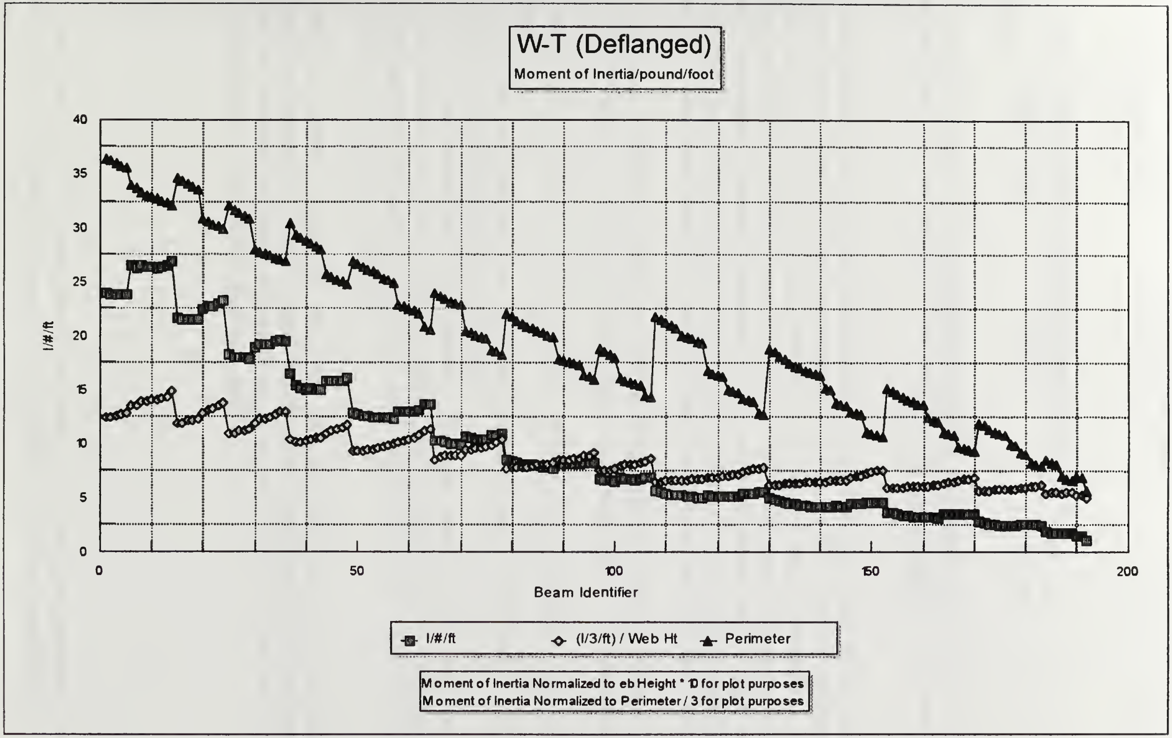


Figure 9d-2 "I-T" Beam Characteristics

Discounted Fuel Costs:

$$\text{Discounted Fuel Cost} = \frac{\text{(ASSET Fuel Cost per Ship)}}{\text{(ELS)}} * \frac{\text{(1+D)^ELS-1)}}{\text{(D*(1\_D)^ELS)}}$$

Expected Life of Ship (ELS) = 40 years

Discount Rate (D) = 10%

Appendix 10 Sample letter soliciting expert opinion follows:

From: John Barentine, MIT 3 Mar 96
To: Dr. Jim Wilkins, Jr

Subj: Expert Opinion Concerning Structural Producibility Issues

Dr. Wilkins,

Thanks for taking my numerous telephone calls. I appreciate your interest in my research area and am grateful for you patiently "weeding the chaff from the wheat" while answering my questions.

1. As I outlined on the telephone the other day, my thesis provides a tool which integrates an existing naval ship preliminary design synthesis tool (ASSET), a commercial finite element structural analysis tool (MAESTRO), refinements to an existing structural construction cost estimating tool (NSRP 0398) with a new life cycle cost and performance assessment tool. The tool allows the designer a method of assessing the cost and performance impacts associated with certain structural parameters which affect producibility. The structural parameters considered are shell thickness, variety and number of structural shape sizes, and the use of parallel mid-body.

The major benefit of this tool is that it allows some assessment at the preliminary design stage of the cost impact associated with details often not considered until the detail design stage.

2. As we discussed, there are three (3) areas wherein I am seeking your expert opinion.[41] These areas are:

a. favorable endorsement to an empirical approach quantifying the tendency of thin steel plate to distort following stiffener welding;
b. favorable endorsement to an empirical approach quantifying the man-hour savings associated with using fewer primary structural "pieces" in the design of a midship section;
c. favorable endorsement to an empirical approach quantifying the cost savings associated with the use of parallel middle body.

3. We know distortion occurs. We also know you must either prevent it, through the use of strong backs, or correct it by flame (or other) straightening. These corrective actions incur a cost. If this cost is non-trivial, as general agreement suggests, and if this cost is not factored into the design, the design does not represent the best it could be.

---

[41] Should any of the SP-4 participants be interested in contributing any charitable assistance to my education by providing comments (written or verbal), it would be tremendously appreciated. (Collect 617.253.4342 or 508.475.7644)

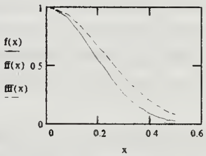
More to the point, my position is that there is a cost savings and a performance increase, associated with using thicker steel plates/shell since the thicker steel will develop less distortion to correct. Yes, it is true, I propose to make the ship cost less and perform better by making it weigh more.

It is known that many variables affect the post-welding distortion. Things such as amount of compressive stress introduced by shot-blasting during preservation, the distance between stiffeners, the consistency of applied heat, the heat input, and many others. But my work is not mature enough to model these items.

My efforts concern order of magnitude issues appropriate for preliminary design. I hope you will bear this in mind as you consider my position, outlined below.

I suggest the following simple measure of the tendency for post-weld distortion to occur, where the only independent variable is the plate thickness. Here, plate thickness is "x":

$x = \frac{1}{64}, \frac{2}{64} .. \frac{32}{64}$ $\quad fff(x) = \exp(-10 \cdot x^2)$ $\quad f(x) = \exp(-15 \cdot x^2)$ $\quad ff(x) = \exp(-20 \cdot x^2)$



What are your thoughts? Based on my limited experience, I suggest the middle curve (f(x)) to be more representative of the average tendency to distort.

4. Now concerning the number of "pieces" which are used to design and fabricate the primary structure of a midship section. The Detail Design of the DDG 51 Flight 1 has at least 33 distinct plate thickness' and structural shape sizes, counting HY-80 separate from HTS. There are certain costs associated with receiving, storing, tracking and otherwise accounting for these "pieces", some of these costs are intrinsic to the midship section design, yet some are a function of the number of "pieces".

Using the factors which determine the "man-hours per unit" you proposed in the formation of the NSRP 0398 spreadsheet, I have formulated relationships for all of the factors which I believe are a function of the number of structural shape types used to produce the midship section. Again, I am not speaking about the total number of plates and stiffeners, but the total number of different types from which the designer may choose when creating the design.[42]

In the following table, "number" represents the sum of different plate thickness' and structural shape sizes from which the designer could choose when producing the midship section design. The factors and there relationship follow:

[42] The rational and criteria used to create a limited number of acceptable stiffener sizes is itself an interesting discussion. If you or others would like more information, please let me know.

Category	NSRP Factor (manhour/unit)	Refinement (manhour/unit)
Material Receipt & Prep	0.1	0.1*(0.35+0.65*number/33)
Piece Marking	0.1	0.1*(0.65+0.35*number/33)
Piece Storing	0.1	0.1*(0.35+0.65*number/33)
Piece Transport	5.0	5.0*(0.65+0.35*number/33)
Piece Lifting	5.0	5.0*(0.85+0.15*number/33)
Piece Blasting	0.1	0.1*(0.85+0.15*number/33)
Piece Coating	0.1	0.1*(0.85+0.15*number/33)

Without going into excess detail concerning my reasons for the individual weighting scheme, it should be clear that for each of the categories, I seek to reward a design which has fewer than the baseline number of "pieces" (33). Yet, in order to be conservative, I am not suggesting that man-hours merely scales with the number of pieces. The first decimal within the parentheses represents that percentage of man-hours which are intrinsic to the operation .

I look forward to your comments.

5. Now, concerning the use of parallel middle body. Not withstanding that there may be some hydrodynamic performance (among other) concerns with the use of parallel middle body on a combatant, I believe that the construction cost will be less than if there were no parallel middle body. How to quantify these savings is the issue.

I believe an effective approach for preliminary design is to apply a learning curve to a repeatable portion within the length of the parallel middle body. Consider a module you are sizing in ASSET, analyzing with MAESTRO and costing in the refined NSRP 0398 spreadsheet. Consider this module to be, say, 40 feet long[43], and the parallel middle body is 120 feet. Then a shipbuilder should be able to construct three (3) identical (from a primary structures perspective) modules. Using conventional weight-based approach, there are no cost savings for the designer/customer for the identical structure.

I believe that a learning curve should be applied to the cost of the 3 modules. For each identical and repeated module after the first, you multiple the module cost by the learning curve factor. I propose a conservative learning curve factor of 0.97, so if the first module is estimated to cost \$100, the second module is estimated to cost \$100*0.97, the third module is estimated to cost \$100 *0.97*0.97, and so on.

[43] Forty (40) feet is somewhat arbitrary. The length should be some integer multiple of the plate width available for the design.

For parallel middle body lengths which are not integer multiples of the module, I propose to round the ratio down to the nearest integer. So a parallel middle body length of 112 feet and a module length of 40 feet (ratio 2.8:1) results in the use of the learning curve only once, since the 2.8 would be rounded down to 2.

I look forward to your comments.

Very Respectfully,

John Barentine

MIT Rm 5-309
Cambridge, MA 02139

617.253.4342
Fax 617.253.4962

Appendix 11 Sample ASSET STRUCTURES Module Report

There are a total of 15 printed reports which are output from the ASSET STRUCTURES MODULE. Printed Report 3 is provided as an example.

```
PRINTED REPORT NO. 3  WEATHER DECK

DECK MTRL TYPEHY 80
STRINGER PLATE MTRL TYPEHY 80
                              SHELL    STRINGER PLATE
 MODULUS OF ELASTICITY, KSI       29600.0     29600.0
 DENSITY, LBM/FT3              489.02      489.02
 YIELD STRENGTH, KSI              80.00       80.00
 MAX PRIMARY STRENGTH, KSI        23.52       23.52
 ALLOWABLE WORKING STRENGTH, KSI    55.00       55.00

HULL LOADS INDCALC
                  MAX      MIN
STIFFENER SPACING, IN     28.00    28.00
STRINGER PLATE WIDTH, FT    7.50

SEGMENT GEOMETRY
   NODE COORD, FTSCND. LOAD, FT
 SEG   YIB    ZIB    YOB    ZOB      HEAD1   HEAD2
  1    0.00   41.84  11.24  41.84     8.38
  2   11.24   41.84  24.73  41.84     8.38
  3   24.73   41.84  33.24  41.84     8.35

SEGMENT SCANTLINGS
     SCANTLINGS OF STIFFENED PLATES
          STIFFENERS             CATLG NO.OF  PLATE  SPACING
 SEG  INXINXIN/IN  NO  STIFF TK, IN   IN
 1 *R  4.920X  2.000X  0.120/  0.180  4.  4  0.4375   26.97
 2 *R  4.920X  2.000X  0.120/  0.180  4.  5  0.4375   26.99
 3 *R  4.920X  2.000X  0.120/  0.180  4.  3  0.3750   25.53
 NOTE: *R STANDS FOR ROLLED SHAPE

SEGMENT PROPERTIES
   PROPERTIES OF STIFFENED PLATES
   AREA  N.A. TO  SEC MOD         SMEAR
    TOTAL  SHEAR  PLATE        PLATE  FLANGE  WT/FT    RATIO
 SEG   IN2    IN2     IN       IN3    IN3   LBF/FT
 1   12.80   0.66    0.50    30.09   3.00   43.46   0.08
 2   12.81   0.66    0.50    30.11   3.00   43.50   0.08
 3   10.57   0.66    0.53    27.75   2.95   35.91   0.10
```

Main Spreadsheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	See HIJACK picture at EH1																	
2	This spreadsheet is used for a four (4) deck FF or DDO																	
3																		
4																Point added to facilitate MAESTRO endpoint loc		
5			ASSET Point ID in feet								MAESTRO Point ID in inches					Point added to describe bottom shell floor***		
6	1 Copy ASSET info into cell A8																	
7	2 Parse info into cells C8 I34 (for a frigate or destroyer w/ WD, 4 ID's & IB)										NOTE MAESTRO orientation aligns "Z" axis in the transverse (athwartship) direction							
8										**NOTE add'l side shell plate since ID-1 does not align w/ HY80 - HTS transition								
9				YIB	ZIB	YOB	ZOB	Head 1	Head 2		Y	Z	Y	Z	Node Length		MAESTRO	MAESTRO
10											inboard	inboard	outboard	outboard			Y	Z
11																		
12		WEATHER DE	1	0	41 84	11 24	41 84	8 38			502 08	0	502.08	134 88	134 88		502 08	0
13			2	11.24	41 84	24 73	41 84	8 38			502.08	134 88	502.08	296.76	161 88		502 08	134 88
14			3	24.73	41 84	33 24	41 84	8 35			502 08	296.76	502.08	398 88	102.12		502 08	296 76
15		SIDE SHELL	1	33 24	41 84	31 66	33 09	8 45			502 08	398 88	397 08	379.92	106.698086		502 08	398 88
16			2	31.66	33 09	29 95	23 33	17 63		**See note	397 08	379 92	387 96	378.36	9.25245913		397 08	379 92
17			3	29 95	23 33	28 16	14 75	26 81			387 96	378 36	279.96	359 4	109.651637		387 96	378 36
18			4	28 16	14 75	24 14	7 08	35 19			279 96	359 4	177	337 92	105 176765		279 96	359 4
19		BOTTOM SHE	1	24.14	7 08	22 25	5.5	39 58			177	337 92	84 96	289 68	103 915635		177	337 92
20			2	22 25	5.5	17 45	2 93	41.79			84 96	289.68	66	267	29 5611908		84 96	289 68
21			3	17.45	2 93	11 37	1 15	43 95			66	267	35.16	209.4	65.3365564		66	267
22			4	11 37	1 15	4 49	0 18	45 31			35 16	209 4	13 8	136 44	76 0224388		35 16	209 4
23			5	4 49	0 18	0	0	45 77			13 8	136 44	2.16	53 88	83 3765147		13 8	136 44
24		INNER BOTTO	1	22 25	5 5	18 75	5 5	2 8	41 97		2 16	53 88	0	0	53 9232788		2 16	53 88
25			2	18 75	5 5	17 45	4 58	2 55	40 92		66	267	66	225	42	**	0	0
26			3	17 45	4 58	11 37	4 58	2 88	39 80		66	225	54 96	209 4	19 1112951	***	66	225
27			4	11 37	4 58	4 49	4 58	2 96	36 63		54 96	209 4	54 96	136 44	72.96		54 96	209 4
28			5	4 49	4 58	0	4 58	2 94	33 78		54 96	136 44	54 96	53 88	82.56		54 96	136 44
29		INT'L DECK 1	1	0	32 33	11 24	32 33	2 67	33 03		54 96	53 88	54 96	0	53 88		54 96	53 88
30			2	11.24	32 33	24 73	32 33	2 67	39 06		387.96	0	387.96	134 88	134 88		54 96	0
31			3	24 73	32 33	31 53	32 33	2 67	29 82		387 96	134 88	387 96	296 76	161 88		387 96	0
32		INT'L DECK 2	1								387.96	296 76	387 96	378 36	81.6		387 96	134 88
33			2								0	0	0	0	0		387 96	296 76
34			3								0	0	0	0	0		0	0
35		INT'L DECK 3	1								0	0	0	0	0		0	0
36			2								0	0	0	0	0		0	0
37		INT'L DECK4	1								0	0	0	0	0		0	0
38			2								0	0	0	0	0		0	0
39		FLOOR	1	54 96	0	0	0				0	0	0	0	0		0	0
40			2	54 96	53 88	2.16	53 88				54.96	0	0	0	54 96		0	0
41			3	54 96	136 44	13 8	136 44				54 96	53 88	2.16	53 88	52 8			
42			4	54 96	209 4	35 16	209 4				54 96	136 44	13 8	136 44	41.16			
43											54 96	209 4	35 16	209 4	19 8			
44		O1 (half)																
45		O2																
46		O3																
47		G20 (half)																
48		G21																
49		G22																
50		G23 (half)																
51		O24																
52		G25																
53		O26 (half)																
54		G27																
55		O28 (half)																
56		G29																
57																		

A	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1																		
2																		
3																		
4	ations **																	
5																MATERIAL	MS=1	HTS=2
6												a (ft) =	8	sections=	4			
7																		
8																		
9	MAESTRO	MAESTRO	TWEEN	Node length/28"		Node length/26"		Node length/24"		Node length/22"		Detail Design	Null entry	t(in)	HSW	TSW	BSF	TSF
10	Separator	endpoint	Deck Ht		# Stiffeners		# Stiffeners		# Stiffeners		# Stiffeners	# Stiffeners	for MAESTRO					
11					28" centers		26" centers		24" centers		22" centers							
12	!	1	114 12	4 81714286	4	5 18769231	5	5 62	5	6 13090909	6	5	0	0 4375	5.685	0 17	3 94	0.215
13	!	2	114 12	5.78142857	5	6 22615385	6	6 745	6	7 35818182	7	4	0	0.4375	5.685	0 17	3 94	0 215
14	!	3	114 12	3.64714286	3	3 92769231	3	4 255	4	4 64181818	4	4	0	0 4375	5 685	0.17	3 94	0 215
15	!	4	114 12	3 81064594	3	4 10377255	4	4 44575359	4	4 84991301	4	4	0	0.5	5.77	0 2	3 97	0.225
16	!	5	9 12	0 33044497	0	0 35586381	0	0 38551913	0	0 42056632	0	0	0	0 4375	7 685	0.17	3 94	0.205
17	!	6	108	3 91612991	4	4 21737067	4	4 56881823	4	4 98416534	5	4	0	0 4375	7 685	0.17	3 94	0 205
18	!	7	102 96	3.75631305	3	4 04526021	4	4 38236523	4	4 78076207	4	4	0	0.375	9 66	0.19	3 96	0 225
19	!	8	92 04	3.71127268	3	3 99675519	3	4 32981813	4	4 72343796	4	4	0	0 4375	9 66	0.19	3 96	0.225
20	!	9	18 96	1.05575681	1	1 13696888	1	1 23171628	1	1 34369049	1	0	0	0 4375	11.685	0 2	3 97	0.225
21	!	10	11 04	2 33344844	2	2 51294448	2	2 72235652	2	2.96984347	2	1	0	0.4375	11.685	0 2	3 97	0 225
22	!	11	n/a	2 7150871	2	2 92393995	2	3 16760162	3	3 4555654	3	2	0	0.5	11 685	0 2	3 97	0 225
23	!	12	n/a	2.97773267	2	3 20678903	3	3 47402144	3	3 78984158	3	2	0	0.5	11 725	0 22	3 99	0.265
24	!	13	n/a	1 92583139	1	2 07397226	2	2 24680328	2	2 45105813	2	1	0	0.75	11.725	0.22	3 99	0.265
25	!	14	n/a	1.5	1	1 61538462	1	1 75	1	1 90909091	1	1	0	0 4375	11 685	0 2	3 97	0 225
26	!	15	11 04	0.68254625	0	0.73504981	0	0 79630396	0	0 86869523	0	0	0	0.4375	11 685	0.2	3 97	0 225
27	!	16	19 8	2 60571429	2	2 80615385	2	3 04	3	3 31636364	3	1	0	0.4375	11 685	0 2	3 97	0 225
28	!	17	41 16	2 94857143	2	3.17538462	3	3 44	3	3 75272727	3	2	0	0 4375	11 685	0.2	3 97	0 225
29	!	18	52 8	1 92428571	1	2 07230769	2	2 245	2	2 44909091	2	1	0	0.4375	11.685	0 2	3 97	0 225
30	!	19	54 96	4 81714286	4	5 18769231	5	5 62	5	6 13090909	6	4	0	0.3125	4 725	0.19	3 96	0 21
31	!	20	387 96	5 78142857	5	6 22615385	6	6 745	6	7 35818182	7	5	0	0.3125	4.725	0.19	3 96	0 21
32	!	21	387 96	2 91428571	2	3 13846154	3	3 4	3	3 70909091	3	3	0	0.3125	4 725	0.19	3 96	0 21
33	!	22	387 96	0	0	0	0	0	0	0	0	4	0	0.3125	5.77	0.2	3 97	0.225
34	!	23	0	0	0	0	0	0	0	0	0	5	0	0.3125	5.77	0.2	3 97	0.225
35	!	24	0	0	0	0	0	0	0	0	0	3	0	0.3125	5.77	0.2	3 97	0.225
36	!	25	n/a	0	0	0	0	0	0	0	0	4	0	0 3125	7.685	0.17	3 94	0 205
37	!	26	0	0	0	0	0	0	0	0	0	7	0	0 3125	7 685	0 17	3 94	0 205
38	!	27	0	0	0	0	0	0	0	0	0	4	0	0 3125	7 685	0 17	3 94	0 205
39	!	28	54 96	0	0	0	0	0	0	0	0	6	0	0.3125	7 685	0.17	3 94	0.205
40	!	29	54 96	1 96285714	1	2 11384615	2	2 29	2	2 49818182	2	1	0	0 5	11 725	0 22	3 99	0.265
41	!	30	n/a	1 88571429	1	2 03076923	2	2.2	2	2 4	2	1	0	0.4375	11.725	0.22	3 99	0 265
42	!	31	n/a	1 47	1	1 58307692	1	1 715	1	1 87090909	1	1	0	0 4375	11.725	0.22	3 99	0.265
43	!	32	n/a	0 70714286	0	0 76153846	0	0 825	0	0 9	0	1	0	0 4375	11 725	0.22	3 99	0 265
44	!											1	n/a	0	17.275	0.15	3	0 425
45	!											1	n/a	0	17.42	0 355	7 495	0.57
46	!											1	n/a	0	17 42	0 355	7 495	0.57
47	!											1	n/a	0	17.275	0 15	3	0 425
48	!											1	n/a	0	17.42	0 355	7 495	0.57
49	!											1	n/a	0	17 42	0.355	7 495	0.57
50	!											1	n/a	0	17.275	0 15	3	0 425
51	!											1	n/a	0	17.42	0.355	7 495	0.57
52												1	n/a	0	17 42	0.355	7 495	0.57
53												1	n/a	0	17.275	0.15	3	0 425
54												1	n/a	0	17 42	0.355	7 495	0 57
55												1	n/a	0	17.275	0 15	3	0 425
56												1	n/a	0	17 42	0 355	7 495	0 57
57																		

Main Spreadsheet

A	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB
1																		
2																		
3																		
4																		
5	HY80=3																	
6													MAESTRO					
7								STIFFENER	FRAME				FRAME					
8			Stiffener					density is 0.283	lbf/in^3									
9			Description	# STIFF	Matl	LINEAR ft	SQUARE ft	WEIGHT	HFW	TFW	BFF	TFF	HFW	TFW	BFF	TFF		SHAPE
10																		
11																		
12	!	WD1	Detail Design	5	3	160	128.333333	985.410528	13.49	0.225	5.025	0.42	13.49	0.225	5.025	0.42	!	
13	!	WD2	Detail Design	4	3	128	102.666667	788.328422	13.49	0.225	5.025	0.42	13.49	0.225	5.025	0.42	!	
14	!	WD3	Detail Design	4	3	128	102.666667	788.328422	13.49	0.225	5.025	0.42	13.49	0.225	5.025	0.42	!	
15	!	SS1	Detail Design	4	2	128	103.893333	889.915008	13.405	0.23	5	0.335	13.405	0.23	5	0.335	!	
16	!	SS2	Detail Design	0	2	0	0	0	13.405	0.23	5	0.335	13.405	0.23	5	0.335	!	
17	!	SS3	Detail Design	4	2	128	124	918.995635	13.405	0.23	5	0.335	13.405	0.23	5	0.335	!	
18	!	SS4	Detail Design	4	2	128	145.28	1185.13336	13.49	0.225	5.025	0.42	13.49	0.225	5.025	0.42	!	
19	!	SS5	Detail Design	4	2	128	145.28	1185.13336	13.49	0.225	5.025	0.42	13.49	0.225	5.025	0.42	!	
20	!	BS1	Detail Design	0	2	0	0	0	15.43	0.295	6.99	0.43	15.43	0.295	6.99	0.43	!	
21	!	BS2	Detail Design	1	2	32	41.7466667	351.037728	0	0	0	0	0	0	0	0	!	floor
22	!	BS3	Detail Design	2	2	64	83.4933333	702.075456	0	0	0	0	0	0	0	0	!	floor
23	!	BS4	Detail Design	2	2	64	83.8133333	790.447526	0	0	0	0	0	0	0	0	!	floor
24	!	BS5	Detail Design	1	2	32	41.9066667	395.223763	0	0	0	0	0	0	0	0	!	floor
25	!	IB1	Detail Design	1	2	32	41.7466667	351.037728	0	0	0	0	0	0	0	0	!	none
26	!	IB2	Detail Design	0	2	0	0	0	0	0	0	0	0	0	0	0	!	none
27	!	IB3	Detail Design	1	2	32	41.7466667	351.037728	0	0	0	0	0	0	0	0	!	none
28	!	IB4	Detail Design	2	2	64	83.4933333	702.075456	0	0	0	0	0	0	0	0	!	none
29	!	IB5	Detail Design	1	2	32	41.7466667	351.037728	0	0	0	0	0	0	0	0	!	none
30	!	ID1-1	Detail Design	4	2	128	92.64	751.727693	11.84	0.23	6.49	0.38	11.84	0.23	6.49	0.38	!	
31	!	ID1-2	Detail Design	5	2	160	115.8	939.659616	11.84	0.23	6.49	0.38	11.84	0.23	6.49	0.38	!	
32	!	ID1-3	Detail Design	3	2	96	69.48	563.79577	11.84	0.23	6.49	0.38	11.84	0.23	6.49	0.38	!	
33	!	ID2-1	Detail Design	4	2	128	103.893333	889.915008	11.84	0.23	6.49	0.38	11.84	0.23	6.49	0.38	!	
34	!	ID2-2	Detail Design	5	2	160	129.866667	1112.39376	11.84	0.23	6.49	0.38	11.84	0.23	6.49	0.38	!	
35	!	ID2-3	Detail Design	3	2	96	77.92	667.436256	11.84	0.23	6.49	0.38	11.84	0.23	6.49	0.38	!	
36	!	ID3-1	Detail Design	4	2	128	124	918.995635	11.84	0.23	6.49	0.38	11.84	0.23	6.49	0.38	!	
37	!	ID3-2	Detail Design	7	2	224	217	1608.24236	11.84	0.23	6.49	0.38	11.84	0.23	6.49	0.38	!	
38	!	ID4-1	Detail Design	4	2	128	124	918.995635	11.84	0.23	6.49	0.38	11.84	0.23	6.49	0.38	!	
39	!	ID4-2	Detail Design	6	0	192	186	1378.49345	11.84	0.23	6.49	0.38	11.84	0.23	6.49	0.38	!	
40	!	F-1	Detail Design	1	0	32	41.9066667	395.223763	n/a	n/a	n/a	n/a	0	0	0	0	!	none
41	!	F-2	Detail Design	1	0	32	41.9066667	395.223763	n/a	n/a	n/a	n/a	0	0	0	0	!	none
42	!	F-3	Detail Design	1	0	32	41.9066667	395.223763	n/a	n/a	n/a	n/a	0	0	0	0	!	none
43	!	F-4	Detail Design	1	0	32	41.9066667	395.223763	n/a	n/a	n/a	n/a	0	0	0	0	!	none
44	!	G1 (half)	Detail Design	1	0	32	54.0666667	420.15312	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
45	!	G2	Detail Design	1	0	32	66.44	1136.3016	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
46	!	G3	Detail Design	1	0	32	66.44	1136.3016	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
47	!	G20 (half)	Detail Design	1	0	32	54.0666667	420.15312	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
48	!	G21	Detail Design	1	0	32	66.44	1136.3016	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
49	!	G22	Detail Design	1	0	32	66.44	1136.3016	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
50	!	G23 (half)	Detail Design	1	0	32	54.0666667	420.15312	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
51	!	G24	Detail Design	1	0	32	66.44	1136.3016	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
52	!	G25	Detail Design	1	0	32	66.44	1136.3016	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
53	!	G26 (half)	Detail Design	1	0	32	54.0666667	420.15312	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
54	!	G27	Detail Design	1	0	32	66.44	1136.3016	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
55	!	G28 (half)	Detail Design	1	0	32	54.0666667	420.15312	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
56	!	G29	Detail Design	1	0	32	66.44	1136.3016	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
57						3264	3521.89333	33256.9465										

Main Spreadsheet

A	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	BT
1															"NUM" different	scantlings=		
2															# stiffeners	7		
3															# frames	10		
4															# girders	5		
5									ORIENTATION	FLAT=1	VERT=2	OVHD=3			# plates	8		
6											SHAPE	FLAT=1	CURVE=2			30		
7					FRAME	Plate			ASSEMBLY	ERECTION					Matl Rec&Prep		Matl Rec&Prep	Auto Flame Cut
8												Plate			(SStage=1)		(SStage=1)	(SStage=1)
9		Matl	LINEAR ft	SQUARE ft	WEIGHT	PMatl	B(m)	Edges	ORIENT	ORIENT	SHAPE	LINEAR ft	SQUARE ft	WEIGHT				
10																		
11																		
12	WD1	3	44 96	69 3695333	785 674516	3	134 88	2	1	1	2	64	359 68	6412.73472	557.382867	1	5.57382867	64
13	WD2	3	53 96	83 2557833	942 949219	3	161 88	1	1	1	2	32	431 68	7696 42272	617 60245	1	6 1760245	32
14	WD3	3	34 04	52 5208833	594 847877	3	102 12	1	1	1	2	32	272.32	4855.19328	427.50755	1	4 2750755	32
15	SS1	3	35 5660287	54 5493966	574.699985	3	106 698086	1	1	2	2	32	284 52823	5797 54721	442 97096	1	4 4297096	32
16	SS2	2	3 08415304	4 73031973	49 8358341	2	9 25245913	0	1	2	2	0	24.6732244	439 898917	29 4035441	1	0 29403544	0
17	SS3	2	36 5505458	56 0593997	590 608479	2	109 651637	1	1	2	2	32	292 404367	5213.27745	472 463766	1	4 72463766	32
18	SS4	2	35 0589218	54 0929948	612 653502	2	105 176765	1	1	2	2	32	280 471375	4286 16355	479 844369	1	4 79844369	32
19	SS5	2	34 638545	53 4443884	605 307431	2	103 915635	2	1	2	2	64	277 10836	4940.56495	475 832748	1	4 75832748	64
20	BS1		9 85373026	18 4100527	252 900321	2	29 5611908	0	1	1	2	0	78 8298421	1405 45725	97 2398948	1	0 97239895	0
21	BS2		21.7788521	0	0	2	65 3365564	0	1	1	2	0	174 230817	3106 36124	215 977484	1	2 15977484	0
22	BS3		25 3408129	0	0	2	76 0224388	1	1	1	2	32	202 726503	4130 75523	286 219837	1	2 86219837	32
23	BS4		27 7921716	0	0	2	83 3765147	1	1	1	2	32	222 337372	4530 3463	306 150706	1	3 06150706	32
24	BS5		17 9744263	0	0	2	53 9232788	1	1	1	1	32	143 79541	4394 96292	185.702077	1	1 85702077	32
25	IB1		14	0	0	2	42	1	1	1	1	32	112	1996 848	153 746667	1	1 53746667	60
26	IB2		6 3704317	0	0	2	19 1112951	1	1	1	1	32	50 9634536	908 627414	50 9634536	1	0 50963454	44 7408634
27	IB3		24.32	0	0	2	72 96	1	1	1	1	32	194 56	3468 81024	236 306667	1	2 36306667	80 64
28	IB4		27.52	0	0	2	82 56	0	1	1	1	0	220.16	3925 23264	303 653333	1	3 03653333	55 04
29	IB5		17 96	0	0	2	53 88	0	1	1	1	0	143 68	2561 67072	185.426667	1	1 85426667	35 92
30	ID1-1	2	44 96	68 6764	792 33918	2	134 88	0	1	1	1	0	359 68	4580 5248	520.9964	1	5.209964	0
31	ID1-2	2	53.96	82 4239	950 948002	2	161 88	1	1	1	1	32	431 68	5497 4448	629 9039	1	6 299039	32
32	ID1-3	2	27.2	41 548	479 351105	2	81 6	2	1	1	1	64	217 6	2771.136	328 628	1	3 28628	64
33	ID2-1	2	0	0	0	2	0	0	1	1	1	0	0	0	103 893333	1	1 03893333	0
34	ID2-2	2	0	0	0	2	0	0	1	1	1	0	0	0	129 866667	1	1 29866667	0
35	ID2-3	2	0	0	0	2	0	0	1	1	1	0	0	0	77 92	1	0 7792	0
36	ID3-1	2	0	0	0	2	0	0	1	1	1	0	0	0	124	1	1 24	0
37	ID3-2	2	0	0	0	2	0	0	1	1	1	0	0	0	217	1	2 17	0
38	ID4-1	2	0	0	0	2	0	0	1	1	1	0	0	0	124	1	1 24	0
39	ID4-2	2	0	0	0	2	0	0	1	1	1	0	0	0	186	1	1 86	0
40	F-1		18.32	0	0	2	54 96	2	1	2	1	64	146 56	2986 30656	188.466667	1	1 88466667	100 64
41	F-2		17 6	0	0	2	52 8	2	1	2	1	64	140.8	2510.3232	182.706667	1	1 82706667	99 2
42	F-3		13 72	0	0	2	41 16	2	1	2	1	64	109 76	1956 91104	151.666667	1	1 51666667	91 44
43	F-4		6 6	0	0	2	19 8	2	1	2	1	64	52.8	941 3712	94 7066667	1	0 94706667	77 2
44	G1 (half)	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	54 0666667	1	0 54066667	n/a
45	G2	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	66 44	1	0 6644	n/a
46	G3	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	66 44	1	0 6644	n/a
47	O20 (half)	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	54 0666667	1	0 54066667	n/a
48	G21	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	66 44	1	0 6644	n/a
49	O22	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	66 44	1	0 6644	n/a
50	O23 (half)	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	54 0666667	1	0 54066667	n/a
51	O24	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	66 44	1	0 6644	n/a
52	G25	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	66 44	1	0 6644	n/a
53	O26 (half)	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	54 0666667	1	0 54066667	n/a
54	G27	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	66 44	1	0 6644	n/a
55	G28 (half)	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	54 0666667	1	0.54066667	n/a
56	G29	n/a	0	0	0		n/a	n/a	1	1	1	n/a	n/a	n/a	66 44	1	0 6644	n/a
57			653 128619	639 081052	7232.11545							832	5225 02895	91314 8924			93 8600334	

Main Spreadsheet

A	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL
1																		
2																		
3																		
4																		
5																		
6																		
7			Auto Flame Cut	Manl Flame Cut		Manl Flame Cut	Edge Prep Flat		Edge Prep Flat	Edge Prep Vert		Edge Prep Vert	Edge Prep Ovhd		Edge Prep Ovhd	Shape - Roll	Shape - Roll	Shape - Line Ht
8	Auto ?	Stage	(SStage=1)	(SStage=2)		(SStage=2)	(SStage=1)		(SStage=1)	(SStage=2)		(SStage=2)	(SStage=2)		(SStage=2)	(SStage=1)	(SStage=1)	(SStage=1)
9																# of Shapes		
10																		
11																		
12	1	1	3.2	76 7766667	1	6 9099	612 902083	1	18 3870625	20 496	2	1.0248	0	2	0	10	1 2	11
13	1	1	1.6	39.5683333	1	3.56115	579 1	1	17.373	18 196	2	0 9098	0	2	0	9	1 2	9
14	1	1	1 6	61 6916667	1	5.55225	439 66	1	13.1898	16 204	2	0 8102	0	2	0	9	1.12	9
15	1	1	1 6	30.4113477	1	2 73702129	440 962201	1	17.638488	25 7382695	2	1.54429617	0	2	0	9	1.14	9
16	1	1	0	7.67707652	1	0 69093689	21 5890713	1	0 64767214	6 4434153	2	0.32217077	0	2	0	5	0 8	4
17	1	1	1 6	70 9102729	1	6 38192456	447 853821	1	13.4356146	26 4650546	2	1 32325273	0	2	0	9	1.12	9
18	1	1	1 6	32.7811276	1	2 95030148	437 412453	1	13.1223736	27 0175588	2	1.35087794	0	2	0	4	0 8	9
19	1	1	3.2	32 5709392	1	2 93138453	498 469815	1	14 9540945	26 9755212	2	1.34877606	0	2	0	9	1 12	10
20	1	1	0	12.4001985	1	1 11601786	76 4494451	1	2 29348335	0 98537303	2	0 04926865	0	2	0	4	0 8	4
21	1	1	0	26.5444261	1	2 38899835	185 756548	1	5 57269645	5 37788521	2	0.26889426	0	2	0	4	0 8	5
22	1	1	1 6	43 9804065	1	3 95823658	307 994857	1	12 3197943	8 93408129	2	0.53604488	0	2	0	7	0 98	7
23	1	1	1.6	45 3260858	1	4 07934772	325.154368	1	13.0061747	9 17921716	2	0.55075303	0	2	0	7	0 98	7
24	1	1	2 24	24.7022131	1	2 96426558	223.130567	1	13.387834	4 99744263	2	0 59969312	0	2	0	6	0 92	0
25	1	1	3	22.655	1	2 03895	195 304583	1	5 8591375	4 6	2	0.23	0	2	0	6	0 56	0
26	1	1	2 23704317	3.18521585	1	0 28666943	108 593022	1	3.25779066	0.63704317	2	0 03185216	0	2	0	1	0 48	0
27	1	1	4.032	27 815	1	2.50335	267.544583	1	8 0263375	5 632	2	0.2816	0	2	0	2	0.56	0
28	1	1	2.752	45.07	1	4 0563	259 249167	1	7.777475	9 152	2	0 4576	0	2	0	3	0 64	0
29	1	1	1 796	24 635	1	2.21715	159 024583	1	4 7707375	4 996	2	0 2498	0	2	0	2	0 56	0
30	1	1	0	63.33	1	5 6997	451 725	1	9 0345	17 296	2	0.69184	0	2	0	9	0.72	0
31	1	1	1 6	76.515	1	6 88635	611 44875	1	12 228975	21 396	2	0.85584	0	2	0	10	0 8	0
32	1	1	3 2	45.765	1	4 11885	422 68125	1	8 453625	12 32	2	0 4928	0	2	0	8	0 64	0
33	1	1	0	45.07	1	4 0563	137 356667	1	2.74713333	12 8	2	0.512	0	2	0	9	0 72	0
34	1	1	0	54.81	1	4 9329	170.168333	1	3 40336667	16	2	0 64	0	2	0	10	0 8	0
35	1	1	0	35.33	1	3 1797	104 545	1	2 0909	9 6	2	0.384	0	2	0	8	0 64	0
36	1	1	0	52 61	1	4.7349	137 985	1	2.7597	12 8	2	0.512	0	2	0	9	0 72	0
37	1	1	0	87.485	1	7 87365	236 89125	1	4 737825	22 4	2	0 896	0	2	0	12	0 96	0
38	1	1	0	52.61	1	4 7349	137 985	1	2.7597	12 8	2	0 512	0	2	0	9	0 72	0
39	1	1	0	75 86	1	6 8274	203 9225	1	4.07845	19 2	2	0.768	0	2	0	11	0 4	0
40	1	1	5.032	24 875	1	2.23875	288 24	1	11 5296	6 34158333	2	0.380495	0	2	0	n/a	n/a	0
41	1	1	4 96	11.4191667	1	1 027725	283 2	1	8 496	6 26958333	2	0.31347917	0	2	0	n/a	n/a	0
42	1	1	4.572	9 47916667	1	0 853125	256.04	1	7 6812	5 88158333	2	0.29407917	0	2	0	n/a	n/a	0
43	1	1	3 86	5 91916667	1	0 532725	206 2	1	6 186	5 16958333	2	0.25847917	0	2	0	n/a	n/a	0
44	1	1	n/a	3.37916667	1	0	33 6895833	1	0	3 2	2	0	0	2	0	4	0 32	0
45	1	1	n/a	4 1525	1	0	34 07625	1	0	3 2	2	0	0	2	0	4	0 32	0
46	1	1	n/a	4 1525	1	0	34 07625	1	0	3 2	2	0	0	2	0	4	0 32	0
47	1	1	n/a	3 37916667	1	0	33 6895833	1	0	3 2	2	0	0	2	0	4	0 32	0
48	1	1	n/a	24 915	1	0	34 07625	1	0	3 2	2	0	0	2	0	4	0 32	0
49	1	1	n/a	24 915	1	0	34 07625	1	0	3 2	2	0	0	2	0	4	0.32	0
50	1	1	n/a	20.275	1	0	33.6895833	1	0	3 2	2	0	0	2	0	4	0 32	0
51	1	1	n/a	24 915	1	0	34.07625	1	0	3 2	2	0	0	2	0	4	0.32	0
52	1	1	n/a	4 1525	1	0	34 07625	1	0	3 2	2	0	0	2	0	4	0 4	0
53	1	1	n/a	3.37916667	1	0	33 6895833	1	0	3 2	2	0	0	2	0	4	0 4	0
54	1	1	n/a	4 1525	1	0	34 07625	1	0	3 2	2	0	0	2	0	4	0 4	0
55	1	1	n/a	3 37916667	1	0	33 6895833	1	0	3.2	2	0	0	2	0	4	0 4	0
56	1	1	n/a	4 1525	1	0	34 07625	1	0	3 2	2	0	0	2	0	4	0 4	0
57			56 8810432			115.021129			271.206541			19 4006923			0		27.46	

Main Spreadsheet

A	CM	CN	CO	CP	CQ	CR	CS	CT	CU	CV	CW	CX	CY	CZ	DA	DB	DC	DD
1																		
2																		
3																		
4																		
5																		
6																		
7	Shape - Line Ht	Fit-Up &		Fit-Up &					Auto Weld	Auto Weld	Auto Weld	Auto Weld	Man Weld	Man Weld	Man Weld	Man Weld	Man Weld	Man Weld
8	(SStage=1)	Assembly		Assembly	Distortion	Distortion	Distortion	Distortion	- Fillet	- Fillet	- Butt	- Butt	- Fillet Down	- Fillet Down	- Butt Down	- Butt Down	- Butt Vert	- Butt Vert
9																		
10																		
11																		
12	11	277.77625	2	155.5547	359 68	0 05663695	0 79588867	49 6193075	0	0	0	0	409 92	94 2816	194 906667	194 906667	0	0
13	9	260 724167	2	146 005533	431 68	0 05663695	0.79588867	59 5519981	0	0	0	0	363 92	83 7016	128 99	128 99	0	0
14	9	225 864167	2	126 483933	272.32	0.05663695	0.79588867	37 567643	0	0	0	0	324 08	74 5384	119 03	119 03	0	0
15	9	228.554717	2	127 990641	284.52823	0 02351775	0 90958705	44 85922	0	0	0	0	327 132057	111 2249	64	83 2	56 0263477	109 251378
16	4	40 4647678	2	22 66027	24 6732244	0 05663695	0.79588867	3 40377087	0	0	0	0	6 16830609	1.4187104	0	0	13 8120765	23 0201275
17	9	230 905955	2	129 307335	292 404367	0 05663695	0.79588867	40 3383624	0	0	0	0	329 101092	75.6932511	64	64	61.5452729	102 575455
18	9	228 978947	2	128 22821	280 471375	0 12131376	1 02328543	49 7470603	0	0	0	0	326 117844	75 007104	64	64	66 1927942	110 321324
19	10	228 243287	2	127 816241	277 10836	0 05663695	0 79588867	38 2282165	0	0	0	0	325 27709	74.8137307	128	128	65 9826058	109 97101
20	4	52 9806946	2	29 669189	78 8298421	0 05663695	0 79588867	10 8748948	0	0	0	0	19 7074605	4 53271592	19 8735318	19 8735318	0	0
21	5	103.417575	2	57.9138418	174 230817	0 05663695	0 79588867	24 0358443	0	0	0	0	107 557704	24.738272	21 3260927	21 3260927	0	0
22	7	142.955589	2	80 05513	202 726503	0 02351775	0 90958705	31.9622163	0	0	0	0	178 681626	60 7517528	97 5437398	126 806862	0	0
23	7	147.255467		82 4630615	222 337372	0 02351775	0 90958705	35 0541003	0	0	0	0	183 584343	62 4186767	98 8494191	128 504245	0	0
24	0	96 7648293		54 1883044	143 79541	0 00021659	1 36438057	34 0065551	99 9488526	7 7960105	64	37 12	0	0	19 4638798	35.0349836	0	0
25	0	89 8045833	2	50 2905667	112	0 05663695	0 79588867	15 450852	92	4 968	64	30.72	0	0	17.4366667	17 4366667	0	0
26	0	43 1482555	2	24 1630231	50 9634536	0 05663695	0 79588867	7 03061409	12 7408634	0 68800662	64	30 72	0	0	3.18521585	3.18521585	0	0
27	0	107 864583	2	60 4041667	194 56	0 05663695	0 79588867	26 8403372	112 64	6 08256	64	30 72	0	0	22.5966667	22 5966667	0	0
28	0	146 769167	2	82 1907333	220.16	0 05663695	0 79588867	30 3719605	183 04	9 88416	0	0	0	0	34 6333333	34 6333333	0	0
29	0	96 7345833	2	54 1713667	143 68	0.05663695	0 79588867	19 8212358	99 92	5 39568	0	0	0	0	19 4166667	19 4166667	0	0
30	0	244 63	2	136.9928	359 68	0.2311141	1 30753138	81.5174338	345 92	13 8368	0	0	0	0	57.86	35 8732	0	0
31	0	293 10375	2	164.1381	431.68	0.2311141	1 30753138	97 8354254	427 92	17 1168	64	30 72	0	0	68.15	42.253	0	0
32	0	180.82625	2	101.2627	217 6	0.2311141	1 30753138	49 3165969	246 4	9 856	128	61 44	0	0	43.19	26 7778	0	0
33	0	166 301667	2	93 1289333	0	0 2311141	1 30753138	0	256	10.24	0	0	0	0	38 1933333	23 6798667	0	0
34	0	199 113333	2	111 503467	0	0.2311141	1 30753138	0	320	12 8	0	0	0	0	44 6866667	27 7057333	0	0
35	0	133 49	2	74 7544	0	0 2311141	1 30753138	0	192	7 68	0	0	0	0	31.7	19 654	0	0
36	0	166 93	2	93.4808	0	0.2311141	1 30753138	0	256	10 24	0	0	0	0	43 22	26 7964	0	0
37	0	265 83625	2	148 8683	0	0 2311141	1 30753138	0	448	17 92	0	0	0	0	66 47	41 2114	0	0
38	0	166 93	2	93 4808	0	0.2311141	1 30753138	0	256	10 24	0	0	0	0	43.22	26 7964	0	0
39	0	232 8675	2	130.4058	0	0.2311141	1 30753138	0	384	15 36	0	0	0	0	58 72	36 4064	0	0
40	0	97 3695833	2	54 5269667	146 56	0 02351775	0 90958705	23.1069068	100 64	6.5416	128	61 44	0	0	0	0	0	0
41	0	96 1095833	2	53 8213667	140 8	0 05663695	0 79588867	19.4239282	99 2	5 3568	128	61 44	0	0	0	0	0	0
42	0	89 3195833	2	50 0189667	109 76	0 05663695	0 79588867	15.1418349	91 44	4 93776	128	61 44	0	0	0	0	0	0
43	0	76 8595833	2	43 0413667	52 8	0.05663695	0 79588867	7.28397308	77.2	4 1688	128	61 44	0	0	0	0	0	0
44	0	65 6895833	3	0	0	1	0	0	64	0	0	0	0	0	13 5166667	0	0	0
45	0	66.07625	4	0	0	1	0	0	64	0	0	0	0	0	16 61	0	0	0
46	0	66.07625	5	0	0	1	0	0	64	0	0	0	0	0	16 61	0	0	0
47	0	65 6895833	6	0	0	1	0	0	64	0	0	0	0	0	13 5166667	0	0	0
48	0	66.07625	3	0	0	1	0	0	64	0	0	0	0	0	16 61	0	0	0
49	0	66 07625	4	0	0	1	0	0	64	0	0	0	0	0	16 61	0	0	0
50	0	65 6895833	5	0	0	1	0	0	64	0	0	0	0	0	13.5166667	0	0	0
51	0	66 07625	6	0	0	1	0	0	64	0	0	0	0	0	16 61	0	0	0
52	0	66.07625		0	0	1	0	0	64	0	0	0	0	0	16 61	0	0	0
53	0	65 6895833		0	0	1	0	0	64	0	0	0	0	0	13 5166667	0	0	0
54	0	66.07625		0	0	1	0	0	64	0	0	0	0	0	16 61	0	0	0
55	0	65.6895833		0	0	1	0	0	64	0	0	0	0	0	13.5166667	0	0	0
56	0	66 07625		0	0	1	0	0	64	0	0	0	0	0	16.61	0	0	0
57	93			2888 98101				852.390288		181 108977		467.2		743 120713		1518 09513		455.139294

Main Spreadsheet

A	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	DO	DP	DQ	DR	DS	DT	DU	DV
1																		
2																		
3																		
4																	"IT" -split - used?	
5																		
6																		$/MHR=
7	Man Weld	Man Weld																
8	- Butt Ovhd	- Butt Ovhd	Marking		Store		Transport		Lift		Blast		Coating		Total	Total Support	Total Productio	Labor Cost
9															MHRS	MHRS	MHRS	$
10																		
11																		
12	0	0	15	1.5	15	1.5	15	7.5	15	7.5	1114.76573	36.7872692	1114.76573	36.7872692	633.232404	316.616202	949.848606	35619.3227
13	0	0	13	1.3	13	1.3	13	6.5	13	6.5	1235.2049	40.7617617	1235.2049	40.7617617	555.192629	277.596315	832.788944	31229.5854
14	0	0	13	1.3	13	1.3	13	6.5	13	6.5	855.0151	28.2154983	855.0151	28.2154983	465.198298	232.599149	697.797448	26167.4043
15	0	0	13	1.3	13	1.3	13	6.5	13	6.5	885.94192	29.2360833	885.94192	29.2360833	588.687821	294.34391	883.031731	33113.6899
16	0	0	8	0.8	8	0.8	8	4	8	4	58.8070882	1.94063391	58.8070882	1.94063391	70.7389618	35.3694809	106.108443	3979.0666
17	0	0	13	1.3	13	1.3	13	6.5	13	6.5	944.927532	31.1826086	944.927532	31.1826086	527.46505	263.732525	791.197575	29669.9091
18	0	0	13	1.3	13	1.3	13	6.5	13	6.5	959.688739	31.6697284	959.688739	31.6697284	539.865152	269.932576	809.797727	30367.4148
19	0	0	14	1.4	14	1.4	14	7	14	7	951.665497	31.4049614	951.665497	31.4049614	596.751703	298.375852	895.127555	33567.2833
20	0	0	8	0.8	8	0.8	8	4	8	4	194.47979	6.41783305	194.47979	6.41783305	96.6171665	48.3085832	144.92575	5434.71561
21	0	0	9	0.9	9	0.9	9	4.5	9	4.5	431.954967	14.2545139	431.954967	14.2545139	183.513443	91.7567213	275.270164	10322.6311
22	0	0	11	1.1	11	1.1	11	5.5	11	5.5	572.439674	18.8905092	572.439674	18.8905092	379.813253	189.906627	569.71988	21364.4955
23	0	0	11	1.1	11	1.1	11	5.5	11	5.5	612.301412	20.2059466	612.301412	20.2059466	392.329759	196.164879	588.494638	22068.5489
24	0	0	10	1	10	1	10	5	10	5	371.404154	12.2563371	371.404154	12.2563371	226.627341	113.313671	339.941012	12747.7879
25	0	0	6	0.6	10	1	10	5	10	5	307.493333	10.14728	307.493333	10.14728	163.986199	81.9930997	245.979299	9224.22372
26	0	0	5	0.5	9	0.9	9	4.5	9	4.5	101.926907	3.36358794	101.926907	3.36358794	89.7170254	44.8585127	134.575538	5046.58268
27	0	0	6	0.6	10	1	10	5	10	5	472.613333	15.59624	472.613333	15.59624	207.202565	103.601282	310.803847	11655.1443
28	0	0	6	0.6	10	1	10	5	10	5	607.306667	20.04112	607.306667	20.04112	227.482335	113.741168	341.223503	12795.8814
29	0	0	5	0.5	9	0.9	9	4.5	9	4.5	370.853333	12.23816	370.853333	12.23816	145.129223	72.5646117	217.693835	8163.51881
30	0	0	12	1.2	12	1.2	12	6	12	6	1041.9928	34.3857624	1041.9928	34.3857624	372.747763	186.373881	559.121644	20967.0616
31	0	0	14	1.4	14	1.4	14	7	14	7	1259.8078	41.5736574	1259.8078	41.5736574	480.680844	240.340422	721.021266	27038.2975
32	0	0	13	1.3	13	1.3	13	6.5	13	6.5	657.256	21.689448	657.256	21.689448	327.823548	163.911774	491.735322	18440.0746
33	0	0	12	1.2	12	1.2	12	6	12	6	207.786667	6.85696	207.786667	6.85696	164.237087	82.1185433	246.35563	9238.33613
34	0	0	13	1.3	13	1.3	13	6.5	13	6.5	259.733333	8.5712	259.733333	8.5712	195.826533	97.9132667	293.7398	11015.2425
35	0	0	11	1.1	11	1.1	11	5.5	11	5.5	155.84	5.14272	155.84	5.14272	132.64764	66.32382	198.97146	7461.42975
36	0	0	12	1.2	12	1.2	12	6	12	6	248	8.184	248	8.184	171.2518	85.6259	256.8777	9632.91375
37	0	0	15	1.5	15	1.5	15	7.5	15	7.5	434	14.322	434	14.322	271.281175	135.640588	406.921763	15259.5661
38	0	0	12	1.2	12	1.2	12	6	12	6	248	8.184	248	8.184	171.2518	85.6259	256.8777	9632.91375
39	0	0	14	1.4	14	1.4	14	7	14	7	372	12.276	372	12.276	237.45805	118.729025	356.187075	13357.0153
40	0	0	7	0.7	11	1.1	11	5.5	11	5.5	376.933333	12.4388	376.933333	12.4388	204.358585	102.179293	306.537878	11495.1704
41	0	0	7	0.7	11	1.1	11	5.5	11	5.5	365.413333	12.05864	365.413333	12.05864	193.583646	96.7918229	290.375469	10889.0801
42	0	0	7	0.7	11	1.1	11	5.5	11	5.5	303.333333	10.01	303.333333	10.01	179.275632	89.6378162	268.913449	10084.2543
43	0	0	7	0.7	11	1.1	11	5.5	11	5.5	189.413333	6.25064	189.413333	6.25064	153.019691	76.5098453	229.529536	8607.35759
44	0	0	4	0.4	4	0.4	4	2	4	2	108.133333	3.5684	108.133333	3.5684	12.7974667	6.39873333	19.1962	719.8575
45	0	0	4	0.4	4	0.4	4	2	4	2	132.88	4.38504	132.88	4.38504	14.55448	7.27724	21.83172	818.6895
46	0	0	4	0.4	4	0.4	4	2	4	2	132.88	4.38504	132.88	4.38504	14.55448	7.27724	21.83172	818.6895
47	0	0	4	0.4	4	0.4	4	2	4	2	108.133333	3.5684	108.133333	3.5684	12.7974667	6.39873333	19.1962	719.8575
48	0	0	4	0.4	4	0.4	4	2	4	2	132.88	4.38504	132.88	4.38504	14.55448	7.27724	21.83172	818.6895
49	0	0	4	0.4	4	0.4	4	2	4	2	132.88	4.38504	132.88	4.38504	14.55448	7.27724	21.83172	818.6895
50	0	0	4	0.4	4	0.4	4	2	4	2	108.133333	3.5684	108.133333	3.5684	12.7974667	6.39873333	19.1962	719.8575
51	0	0	4	0.4	4	0.4	4	2	4	2	132.88	4.38504	132.88	4.38504	14.55448	7.27724	21.83172	818.6895
52	0	0	4	0.4	4	0.4	4	2	4	2	132.88	4.38504	132.88	4.38504	14.63448	7.31724	21.95172	823.1895
53	0	0	4	0.4	4	0.4	4	2	4	2	108.133333	3.5684	108.133333	3.5684	12.8774667	6.43873333	19.3162	724.3575
54	0	0	4	0.4	4	0.4	4	2	4	2	132.88	4.38504	132.88	4.38504	14.63448	7.31724	21.95172	823.1895
55	0	0	4	0.4	4	0.4	4	2	4	2	108.133333	3.5684	108.133333	3.5684	12.8774667	6.43873333	19.3162	724.3575
56	0	0	4	0.4	4	0.4	4	2	4	2	132.88	4.38504	132.88	4.38504	14.63448	7.31724	21.95172	823.1895
57		0		38.7		42.3		211.5		211.5		619.47622		619.47622	9525.8173	4762.90865	14288.7259	535827.223

A	DW	DX	DY	DZ	EA	EB	EC	ED	EE	EF	EG	EH	EI	EJ	EK
1															
2															
3															
4	no														
5															
6	37.5														
7															
8	Plate Cost	Stiffener Area	Frame Area	Stiffener Cost	Frame Cost	Matl Cost	Total Cost								
9	$					$	$								
10															
11															
12	3013 98532	1 81355	5 14575	292 90767	723 019763	4029 91275	39649 2355								
13	3617 31868	1 81355	5.14575	255 40767	723 019763	4595.74611	35825 3315								
14	2281 94084	1 81355	5 14575	255 40767	723 019763	3260 36827	29427 7726								
15	2608 89625	2.04725	4 75815	274 766334	675 030657	3558 69324	36672 3832								
16	206 752491	2.11415	4.75815	130 827462	675 030657	1012 61061	4991 67721								
17	2450 2404	2.11415	4 75815	280 827462	675.030657	3406 09852	33076 0076								
18	2014 49687	2 7264	5.14575	350 391176	723 019763	3087 90781	33455 3226								
19	2322 06553	2 7264	5 14575	350 391176	723 019763	3395 47647	36962 7598								
20	660 564909	3 23025	7 55755	279 396256	1012 83143	1952 7926	7387 50821								
21	1459 98978	3.23025	0	316 896256	150	1926 88604	12249 5172								
22	1858 83986	3.23025	0	354 396256	150	2363 23611	23727 7316								
23	2038 65584	3 63685	0	427 168144	150	2615 82398	24684 3729								
24	1845 88443	3 63685	0	389 668144	150	2385.55257	15133 3405								
25	938 51856	3.23025	0	316 896256	150	1405 41482	10629 6385								
26	427 054884	3.23025	0	279 396256	150	856.45114	5903 03382								
27	1630 34081	3 23025	0	316 896256	150	2097 23707	13752 3813								
28	1844 85934	3.23025	0	354.396256	150	2349 2556	15145 137								
29	1203 98524	3 23025	0	316 896256	150	1670 88149	9834 40031								
30	2152 84666	1.72935	5 1894	249 033608	728 283985	3130 16425	24097 2259								
31	2583 79906	1.72935	5.1894	286 533608	728 283985	3598 61665	30636 9141								
32	1302 43392	1.72935	5.1894	211 533608	728 283985	2242 25151	20682 3261								
33	0	2 04725	5.1894	274 766334	728 283985	1003 05032	10241 3864								
34	0	2 04725	5 1894	312.266334	728 283985	1040 55032	12055 7928								
35	0	2 04725	5 1894	237 266334	728 283985	965 550318	8426 98007								
36	0	2.11415	5.1894	280 827462	728 283985	1009 11145	10642 0252								
37	0	2.11415	5.1894	393 327462	728 283985	1121.61145	16381 1775								
38	0	2 11415	5.1894	280 827462	728 283985	1009 11145	10642 0252								
39	0	2 11415	5.1894	355 827462	728 283985	1084 11145	14441 1268								
40	1343 83795	3 63685	0	389 668144	n/a	1733 5061	13228 6765								
41	1179 8519	3 63685	0	389 668144	n/a	1569 52005	12458 6001								
42	919 748189	3 63685	0	389 668144	n/a	1309 41633	11393 6707								
43	442 444464	3 63685	0	389 668144	n/a	832 112608	9439 4702								
44	0	3 86625	0	430 210051	n/a	430 210051	1150 06755								
45	0	10 45625	0	1264 2086	n/a	1264 2086	2082 8981								
46	0	10 45625	0	1264 2086	n/a	1264 2086	2082 8981								
47	0	3 86625	0	430.210051	n/a	430.210051	1150 06755								
48	0	10 45625	0	1264 2086	n/a	1264 2086	2082 8981								
49	0	10.45625	0	1264 2086	n/a	1264 2086	2082 8981								
50	0	3 86625	0	430.210051	n/a	430 210051	1150 06755								
51	0	10 45625	0	1264 2086	n/a	1264 2086	2082 8981								
52	0	10 45625	0	1264 2086	n/a	1264 2086	2087 3981								
53	0	3 86625	0	430 210051	n/a	430 210051	1154 56755								
54	0	10 45625	0	1264 2086	n/a	1264 2086	2087 3981	TUBE Calculations							
55	0	3 86625	0	430 210051	n/a	430.210051	1154 56755	Tube Total	Labor	Material	Total Tube	Scantling	Tube	Total Module	MAESTRO
56	0	10 45625	0	1264 2086	n/a	1264 2086	2087 3981	Manhours	Cost	Cost	Cost	Weight (both)	Weight (both)	Weight (both)	Weight (both)
57	42349 3522			22248 5342	15285 8621	79883 7484	615710 971	384 407792	14415 2922	14239 9221	35599 8052	117 682102	31 7855404	149 467642	132

Main Look-up Tables (A_Original & B_Original)

A	A	B	C	D	E	F	G	H	I	J
124	a_original = COST ESTIMATING PROCESS FACTORS									
125		1	2	3	4	5	6	7	8	
126	THICKNESS	FLAME	FLAME	EDGE PREP	EDGE PREP	EDGE PREP	ASSEMBLY	WELDING-MACHINE		
127	(INCHES)	CUTTING	CUTTING	GRINDING	GRINDING	GRINDING		FILLET	BUTT	
128		AUTO	MANUAL	FLAT	VERTICAL	OVERHEAD				
129	0	0	0	0	0	0	0	0	0	
130	0.005	0.05	0.09	0.02	0.04	0.06	0.56	0.04	0.48	
131	0.25	0.05	0.09	0.02	0.04	0.06	0.56	0.04	0.48	
132	0.375	0.05	0.09	0.03	0.05	0.07	0.56	0.054	0.48	
133	0.5	0.05	0.09	0.04	0.06	0.08	0.56	0.065	0.48	
134	0.75	0.07	0.12	0.06	0.12	0.17	0.56	0.078	0.58	
135	1	0.07	0.16	0.08	0.17	0.26	0.56	0.0936	0.701	
136										
137	b-original									
138		1	2	3	4	5	6	7	8	9
139	THICKNESS	WELDING-MANUAL			WELDING-MANUAL					
140	(INCHES)		FILLET			BUTT		THICKNESS	POSTION	FACTORs
141		DOWN	VERT	OVHD	DOWN	VERT	OVHD	FACTOR*	VERT	OVHD
142	0	0	0	0	0	0	0	0	0	0
143	0.005	0.12	0.24	0.36	0.62	1.24	1.86	0.08	2	3
144	0.25	0.12	0.24	0.36	0.62	1.24	1.86	0.1	2	3
145	0.375	0.23	0.38333333	0.53666667	1	1.66666667	2.33333333	0.12	1.66666667	2.33333333
146	0.5	0.34	0.51	0.68	1.3	1.95	2.6	0.125	1.5	2
147	0.75	0.6	1.2	1.7	1.8	3.6	5.1	0.13	2	2.83333333
148	1	1	2.125	3.25	2.4	5.1	7.8	0.14	2.125	3.25
149								*=revised		

A	L	M	N	O	P	Q	R	S	T	U
124	a_podac									
125	Vlookup "offset	1	2	3	4	5	6	7	8	
126	THICKNESS	FLAME	FLAME	EDGE PREP	EDGE PREP	EDGE PREP	ASSEMBLY	WELDING-MACHINE		
127	(INCHES)	CUTTING	CUTTING	GRINDING	GRINDING	GRINDING		FILLET	BUTT	
128		AUTO	MANUAL	FLAT	VERTICAL	OVERHEAD				
129	0	0	0	0	0	0	0	0	0	
130	0.005	0.00208	0.00741	0.02	0.04	0.06	0.56	0.00555	0.00606	
131	0.25	0.00208	0.00741	0.02	0.04	0.06	0.56	0.00555	0.00606	
132	0.375	0.00276	0.00741	0.03	0.05	0.07	0.56	0.0111	0.00833	
133	0.5	0.00308	0.008	0.04	0.06	0.08	0.56	0.01665	0.0118	
134	0.75	0.00495	0.00975	0.06	0.12	0.17	0.56	0.0222	0.0143	
135	1	0.0087	0.01	0.08	0.17	0.26	0.56	0.02775	0.0236	
136										
137	B_podac									
138		1	2	3	4	5	6	7	8	9
139	THICKNESS	WELDING-MANUAL			WELDING-MANUAL					
140	(INCHES)		FILLET			BUTT		THICKNESS	POSTION	FACTORs
141		DOWN	VERT	OVHD	DOWN	VERT	OVHD	FACTOR	VERT	OVHD
142	0	0	0	0	0	0	0	0	0	0
143	0.005	0.12	0.24	0.36	0.0129	0.02	0.0222	1	2	3
144	0.25	0.12	0.24	0.36	0.0141	0.0286	0.0286	1	2	3
145	0.375	0.23	0.38333333	0.53666667	0.016	0.0513	0.0541	1.2	1.66666667	2.33333333
146	0.5	0.34	0.51	0.68	0.0339	0.1	0.1087	1.2	1.5	2
147	0.75	0.6	1.2	1.7	0.0667	0.2	0.2222	1.2	2	2.83333333
148	1	1	2.125	3.25	0.1053	0.4	0.4545	1.2	2.125	3.25

Distortion Look-up Table

Plate Cost Look-up Table

A	A	B	C	D	E	F	G	H	I	J
157	Lookup C - Distortion Cost Factors						Cost per Pound - Plate			
158	thickness	tendency	cost/lton						1	
159			1	2	3			0	0	KRIEZIS
160	0	0	0	0	0		1/8	0.125	0.49	0.44713923
161	3/64	0.046875	0.9676	600	10.9150446		3/16	0.1875	0.48	0.44327076
162	3/32	0.09375	0.8765	560	10.1873749		1/4	0.25	0.47	0.43940228
163	3/16	0.1875	0.5902	375	6.82190286		5/16	0.3125	0.47	0.4355338
164	7/32	0.21875	0.4878	325	5.91231581		3/8	0.375	0.47	0.43166532
165	1/4	0.25	0.3916	300	5.45752228		7/16	0.4375	0.47	0.42779684
166	9/32	0.28125	0.3053	240	4.36601783		1/2	0.5	0.45	0.42392836
167	5/16	0.3125	0.2311	230	4.18410042		9/16	0.5625	0.45	0.42005989
168	11/32	0.34375	0.1699	175	3.18355467		5/8	0.625	0.45	0.41619141
169	3/8	0.375	0.1213	150	2.72876114		11/16	0.6875	0.42	0.41232293
170	13/32	0.40625	0.0841	115	2.09205021		3/4	0.75	0.42	0.40845445
171	7/16	0.4375	0.0566	100	1.81917409		13/16	0.8125	0.42	0.40458597
172	1/2	0.5	0.0235	100	1.81917409		7/8	0.875	0.4	0.40071749
173	9/16	0.5625	0.0087	100	1.81917409		15/16	0.9375	0.4	0.39684902
174							1	1	0.39	0.39298054

A	A	B	C	D	E	F	G	H	I
65	Sked=	80							
66	Tube Info.								
67	Assumed to	Tube	Wall	Outer	MAESTRO	MAESTRO	Effective	#perModule	Matl Rec&Prep
68	be correct	Material	Thickness	Diam	Space Keeper	Space Keeper	Length		(SStage=1)
69	at Sections						Factor		
70	0&2&4								
71		2	0.365	10.75	.	.	0.7	3	3
72		2	0.365	10.75	.	.	0.7	3	3
73		2	0.365	10.75	.	.	0.7	3	3
74		2	0.365	10.75	.	.	0.7	3	3
75		2	0.365	10.75	.	.	0.7	3	3
76		2	0.365	10.75	.	.	0.7	3	3
77		2	0.365	10.75	.	.	0.7	3	3
78		2	0.365	10.75	.	.	0.7	3	3
79		2	0.365	10.75	.	.	0.7	3	3
80		2	0.365	10.75	.	.	0.7	3	3
81									

Pillar Spreadsheet

A	J	K	L	M	N	O	P	Q	R
65	PROCESS		How is						
66	FACTOR		Tube	MACHINE	MANUAL	#Bends	Type		
67	(MNHRS/	Matl Rec&Prep	Cut?	CUT	CUT		Bends	MACHINE	MANUAL
68	WORK UNIT)	(SStage=1)						BEND	BEND
69									
70									
71	1	0.03	Mach	0.06	0	0	None	0	0
72	1	0.03	Mach	0.06	0	0	None	0	0
73	1	0.03	Mach	0.06	0	0	None	0	0
74	1	0.03	Mach	0.06	0	0	None	0	0
75	1	0.03	Mach	0.06	0	0	None	0	0
76	1	0.03	Mach	0.06	0	0	None	0	0
77	1	0.03	Mach	0.06	0	0	None	0	0
78	1	0.03	Mach	0.06	0	0	None	0	0
79	1	0.03	Mach	0.06	0	0	None	0	0
80	1	0.03	Mach	0.06	0	0	None	0	0
81									

Pillar Spreadsheet

A	S	T	U	V	W	X	Y	Z	AA
65							Fitup,		Surface Prep
66	Marking	HANDLING (KITTING)			#Joints per	WELD	Ass'mbl &	Linear Ft	Prep
67		STORAGE	TRANSPORT	LIFTING	Tube	Socket	Install	Tube	Exterior
68	mh/piece	PIECE	PIECE	PIECE		Joint	Socket		0.033 mhr/sq ft
69	0.1	0.1	0.5	0.5		5			0.033
70									
71	0.3	0.3	1.5	1.5	2	10.2	0.36	9.51	2.64967619
72	0.3	0.3	1.5	1.5	2	10.2	0.36	9.51	2.64967619
73	0.3	0.3	1.5	1.5	2	10.2	0.36	9.51	2.64967619
74	0.3	0.3	1.5	1.5	2	10.2	0.36	9	2.50757999
75	0.3	0.3	1.5	1.5	2	10.2	0.36	9	2.50757999
76	0.3	0.3	1.5	1.5	2	10.2	0.36	9	2.50757999
77	0.3	0.3	1.5	1.5	2	10.2	0.36	8.58	2.39055959
78	0.3	0.3	1.5	1.5	2	10.2	0.36	8.58	2.39055959
79	0.3	0.3	1.5	1.5	2	10.2	0.36	7.67	2.13701539
80	0.3	0.3	1.5	1.5	2	10.2	0.36	7.67	2.13701539
81									

Pillar Spreadsheet

A	AB	AC	AD	AE	AF	AG	AH	AI
65			Tube	Tube	Tube	Tube	Tube	Tube
66	Prep	Coating	Direct	Support	Total	Total	Material	Total
67	Interior		Manhours	Manhours	Labor	Labor	Cost	
68	twice exterior	twice exterior		=25% of Trade	Manhours	Cost	$.4/Lbs	Weight
69	0.066	0.066		0.25	mh	$	0.4	Lbs
70								
71	4.93948937	10.2388417	32.0780073	8.01950183	40.0975091	1503.65659	1538.35805	3845.89512
72	4.93948937	10.2388417	32.0780073	8.01950183	40.0975091	1503.65659	1538.35805	3845.89512
73	4.93948937	10.2388417	32.0780073	8.01950183	40.0975091	1503.65659	1538.35805	3845.89512
74	4.67459562	9.68975559	31.1219312	7.7804828	38.902414	1458.84053	1455.85935	3639.64838
75	4.67459562	9.68975559	31.1219312	7.7804828	38.902414	1458.84053	1455.85935	3639.64838
76	4.67459562	9.68975559	31.1219312	7.7804828	38.902414	1458.84053	1455.85935	3639.64838
77	4.45644783	9.237567	30.3345744	7.5836436	37.918218	1421.93318	1387.91925	3469.79812
78	4.45644783	9.237567	30.3345744	7.5836436	37.918218	1421.93318	1387.91925	3469.79812
79	3.98379427	8.25782504	28.6286347	7.15715868	35.7857934	1341.96725	1240.71569	3101.78923
80	3.98379427	8.25782504	28.6286347	7.15715868	35.7857934	1341.96725	1240.71569	3101.78923
81			307.526234	76.8815584	384.407792	14415.2922	14239.9221	35599.8052

Pipe A Look-up Table

A	A	B	C	D	E	F	G	H	I	J
188	COST ESTIMATING DATA FOR									
189		PIPING (P1)								
190										
191										
192	MATERIAL:	CARBON STEEL								
193	SCHEDULE	80								
194										
195										
196	COST ESTIMATING PROCESS FACTORS									
197										
198		1	2	3	4	5	6	7	8	9
199	PIPE SIZE	CUT	BEND	- - - FIT - - -	- - - -UP - - -	EMBLE & INST	- - - AND - - -	- - INSTALL	PIPE	HYDRO
200	IPS	PIPE	PIPE	BUTT	SOCKET	FLANGE	THREAD	SILBRAZE	INSULATION	TEST
201	0	0	0	0	0	0	0	0	0	0
202	0.125	0.02	0.25	0.6	0.5	NA	NA	NA	0.91	0.15
203	0.25	0.02	0.25	0.8	0.6	NA	NA	NA	0.91	0.27
204	0.5	0.02	0.25	1	0.7	NA	NA	NA	0.91	0.41
205	0.75	0.03	0.25	1.1	0.8	NA	NA	NA	0.91	0.55
206	1	0.03	0.25	1.2	0.9	NA	NA	NA	0.91	0.68
207	1.25	0.04	0.25	1.2	1.1	NA	NA	NA	1.14	0.75
208	1.5	0.05	0.25	1.5	1.2	NA	NA	NA	1.14	0.82
209	2	0.05	0.39	1.7	1.4	NA	NA	NA	1.14	0.96
210	2.5	0.06	0.39	1.9	1.6	NA	NA	NA	1.14	1.09
211	3	0.06	0.39	2.2	1.9	NA	NA	NA	1.23	1.23
212	3.5	0.07	0.39	2.5	2.2	NA	NA	NA	1.33	1.23
213	4	0.08	0.39	2.7	2.4	NA	NA	NA	1.41	1.36
214	5	0.08	0.39	3.1	2.7	NA	NA	NA	1.49	1.5
215	6	0.09	0.39	3.6	3.2	NA	NA	NA	1.71	0.64
216	8	0.15	0.72	4.5	4	NA	NA	NA	2.3	1.77
217	10	0.21	1.61	5.5	4.9	NA	NA	NA	2.58	
218	12	0.26	4.33	6.4	5.9	NA	NA	NA	2.84	
219	14	0.32	4.33	7.4	6.8	NA	NA	NA	3.13	
220	16	0.38	4.33						3.34	

Pipe B Look-up Table

A	A	B	C	D	E	F	G	H
228		WELD FACTORS						
229		BUTT	2					
230		SOCKET	5					
231								
232	SCHEDULE	40	80	160	40	80	160	
233	PIPE SIZE	WELD	WELD	WELD	WELD	WELD	WELD	
234	IPS	BUTT	BUTT	BUTT	SOCKET	SOCKET	SOCKET	
235	0	0	0	0	0	0	0	
236	0.125	3	3	3.1	1.9	1.7	2.2	
237	0.25	3	3	3.1	1.9	1.7	2.2	
238	0.5	3	3	3.1	1.9	1.7	2.2	
239	0.75	3	3	3.1	1.9	1.7	2.2	
240	1	3	3	3.1	1.9	2.2	2.8	
241	1.25	3	3	3.3	2.2	2.5	3.4	
242	1.5	3	3.2	3.3	2.4	3	4.6	
243	2	3	3.4	3.8	3.5	4.5	7.2	
244	2.5	3.5	3.5	4.5				
245	3	4	4	5.8				
246	3.5	4.5	4.7	6.7				
247	4	5	5.2	7.5				
248	5	5.2	5.9	9.9				
249	6	5.4	7.5	13				
250	8	6.5	10	17				
251	10	8.5	13	24				

	A	B	C	D	E	F	G	H	I	J
1	See HIJACK picture at EH1									
2	This spreadsheet is used for a four (4) deck FF or DDG									
3										
4										
5			ASSET Point ID in feet							
6	1 Copy ASSET Info into cell A8									
7	2 Parse info into cells C8..I34 (for a frigate or destroyer w/ WD, 4 ID's & IB)									
8										**NOTE: add'l side shell plate since ID-1 does not align w/ HY80 - HTS transition
9				YIB	ZIB	YOB	ZOB	Head 1	Head 2	
10										
11										
12		WEATHER DECK	1	0	41.84	11 2	41 84	8.38		
13			2	11.24	41 84	24 7	41 84	8 38		
14			3	24.73	41.84	33 2	41 84	8 35		
15		SIDE SHELL	1	33 24	41 84	31.7	33 09	8 45		
16			2	31 66	33.09	30	23 33	17 6		**See note
17			3	29 95	23 33	28 2	14 75	26 8		
18			4	28 16	14 75	24 1	7 08	35 2		
19		BOTTOM SHELL	1	24 14	7 08	22 3	5.5	39 6		
20			2	22.25	5 5	17.5	2 93	41 8		
21			3	17 45	2.93	11 4	1 15	44		
22			4	11 37	1 15	4 49	0 18	45.3		
23			5	4 49	0 18	0	0	45 8		
24		INNER BOTTOM	1	22 25	5 5	18 8	5 5	2 8	41 97	
25			2	18 75	5.5	17 5	4 58	2.55	40.92	
26			3	17 45	4.58	11 4	4 58	2 88	39 80	
27			4	11 37	4 58	4 49	4 58	2 96	36 63	
28			5	4 49	4.58	0	4 58	2.94	33 78	
29		INT'L DECK 1	1	0	32.33	11 2	32 33	2.67	33 03	
30			2	11.24	32 33	24 7	32 33	2 67	39 06	
31			3	24 73	32.33	31.5	32 33	2.67	29 82	
32		INT'L DECK 2	1							
33			2							
34			3							
35		INT'L DECK 3	1							
36			2							
37		INT'L DECK4	1							
38			2							
39		FLOOR	1	+Q30	+R30	+Q25	+R25			
40			2	+Q29	+R29	+Q24	+R24			
41			3	+Q28	+R28	+Q23	+R23			
42			4	+Q27	+R27	+Q22	+R22			
43										
44		G1 (half)								
45		G2								
46		G3								
47		G20 (half)								
48		G21								
49		G22								
50		G23 (half)								
51		G24								
52		G25								
53		G26 (half)								
54		G27								
55		G28 (half)								
56		G29								
57										

	K	L	M	N	O	P	Q	R	S	T	U	V
4						Point added to facilitate MAESTRO endpoint locations **						
5	MAESTRO Point ID in inches					Point added to describe bottom shell floor***						
7	NOTE MAESTRO orientation aligns "Z" axis in the transverse (athwartship) direction											
9	Y	Z	Y	Z	Node Length		MAESTRO	MAESTRO	MAESTR(	MAESTRO	TWEEN	Node length/28"
10	inboard	inboard	outboard	outboard			Y	Z	Separator	endpoint	Deck Ht	
12	+E12*12	+D12*12	+G12*12	+F12*12	@SQRT((N12-L12)^2+(M12-K12)^2)		+K12	+L12	!	1	+$Q12-$Q3	+O12/28
13	+E13*12	+D13*12	+G13*12	+F13*12	@SQRT((N13-L13)^2+(M13-K13)^2)		+K13	+L13	!	2	+$Q13-$Q3	+O13/28
14	+E14*12	+D14*12	+G14*12	+F14*12	@SQRT((N14-L14)^2+(M14-K14)^2)		+K14	+L14	!	3	+$Q14-$Q3	+O14/28
15	+E15*12	+D15*12	+G15*12	+F15*12	@SQRT((N15-L15)^2+(M15-K15)^2)		+K15	+L15	!	4	+$Q15-$Q3	+O15/28
16	+E16*12	+D16*12	+G31*12	+F31*12	@SQRT((N16-L16)^2+(M16-K16)^2)		+K16	+L16	!	5	+$Q16-$Q1	+O16/28
17	+G31*12	+F31*12	+G16*12	+F16*12	@SQRT((N17-L17)^2+(M17-K17)^2)		+K17	+L17	!	6	+$Q17-$Q1	+O17/28
18	+E17*12	+D17*12	+G17*12	+F17*12	@SQRT((N18-L18)^2+(M18-K18)^2)		+K18	+L18	!	7	+$Q18-$Q1	+O18/28
19	+E18*12	+D18*12	+G18*12	+F18*12	@SQRT((N19-L19)^2+(M19-K19)^2)		+K19	+L19	!	8	+$Q19-$Q2	+O19/28
20	+E19*12	+D19*12	+G19*12	+F19*12	@SQRT((N20-L20)^2+(M20-K20)^2)		+K20	+L20	!	9	+$Q20-$Q2	+O20/28
21	+E20*12	+D20*12	+G20*12	+F20*12	@SQRT((N21-L21)^2+(M21-K21)^2)		+K21	+L21	!	10	+$Q21-$Q2	+O21/28
22	+E21*12	+D21*12	+G21*12	+F21*12	@SQRT((N22-L22)^2+(M22-K22)^2)		+K22	+L22	!	11	n/a	+O22/28
23	+E22*12	+D22*12	+G22*12	+F22*12	@SQRT((N23-L23)^2+(M23-K23)^2)		+K23	+L23	!	12	n/a	+O23/28
24	+E23*12	+D23*12	+G23*12	+F23*12	@SQRT((N24-L24)^2+(M24-K24)^2)		+K24	+L24	!	13	n/a	+O24/28
25	+E24*12	+D24*12	+G24*12	+F24*12	@SQRT((N25-L25)^2+(M25-K25)^2)	**	0	0	!	14	n/a	+O25/28
26	+E25*12	+D25*12	+G25*12	+F25*12	@SQRT((N26-L26)^2+(M26-K26)^2)	***	+K26	+L26	!	15	+$Q26-$Q2	+O26/28
27	+E26*12	+D26*12	+G26*12	+F26*12	@SQRT((N27-L27)^2+(M27-K27)^2)		+K27	+L27	!	16	+$Q27-$Q2	+O27/28
28	+E27*12	+D27*12	+G27*12	+F27*12	@SQRT((N28-L28)^2+(M28-K28)^2)		+K28	+L28	!	17	+$Q28-$Q2	+O28/28
29	+E28*12	+D28*12	+G28*12	+F28*12	@SQRT((N29-L29)^2+(M29-K29)^2)		+K29	+L29	!	18	+$Q29-$Q2	+O29/28
30	+E29*12	+D29*12	+G29*12	+F29*12	@SQRT((N30-L30)^2+(M30-K30)^2)		+M29	+N29	!	19	+$Q30-$Q2	+O30/28
31	+E30*12	+D30*12	+G30*12	+F30*12	@SQRT((N31-L31)^2+(M31-K31)^2)		+K30	+L30	!	20	+$Q31-$Q3	+O31/28
32	+E31*12	+D31*12	+G31*12	+F31*12	@SQRT((N32-L32)^2+(M32-K32)^2)		+K31	+L31	!	21	+$Q32-$Q3	+O32/28
33	+E32*12	+D32*12	+G32*12	+F32*12	@SQRT((N33-L33)^2+(M33-K33)^2)		+K32	+L32	!	22	+$Q33-$Q3	+O33/28
34	+E33*12	+D33*12	+G33*12	+F33*12	@SQRT((N34-L34)^2+(M34-K34)^2)		+K33	+L33	!	23	+$Q34-$Q3	+O34/28
35	+E34*12	+D34*12	+G34*12	+F34*12	@SQRT((N35-L35)^2+(M35-K35)^2)		+K34	+L34	!	24	+$Q35-$Q3	+O35/28
36	+E35*12	+D35*12	+G35*12	+F35*12	@SQRT((N36-L36)^2+(M36-K36)^2)		+K35	+L35	!	25	n/a	+O36/28
37	+E36*12	+D36*12	+G36*12	+F36*12	@SQRT((N37-L37)^2+(M37-K37)^2)		+K36	+L36	!	26	+$Q37-$Q3	+O37/28
38	+E37*12	+D37*12	+G37*12	+F37*12	@SQRT((N38-L38)^2+(M38-K38)^2)		+K37	+L37	!	27	+$Q38-$Q4	+O38/28
39	+E38*12	+D38*12	+G38*12	+F38*12	@SQRT((N39-L39)^2+(M39-K39)^2)		+K38	+L38	!	28	+$Q30-$Q3	+O39/28
40	+D39	+E39	+F39	+G39	@SQRT((N40-L40)^2+(M40-K40)^2)		+K39	+L39	!	29	+$Q28-$Q4	+O40/28
41	+D40	+E40	+F40	+G40	@SQRT((N41-L41)^2+(M41-K41)^2)				!	30	n/a	+O41/28
42	+D41	+E41	+F41	+G41	@SQRT((N42-L42)^2+(M42-K42)^2)				!	31	n/a	+O42/28
43	+D42	+E42	+F42	+G42	@SQRT((N43-L43)^2+(M43-K43)^2)				!	32	n/a	+O43/28
44									!			
45									!			
46									!			
47									!			
48									!			
49									!			
50									!			
51									!			

A	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
1																			
2																			
3																			
4																			
5												MATE	MS=1	HTS=2	HY80=3				
6								a (ft) =	8	sections=	4								
7																			
8																	Stiffener		
9		Node length/26"		Node length/24"		Node length/22"		Detail Design	Null entry	t(in)	HSW	TSW	BSF	TSF			Description	# STIFF	Matl
10	# Stiffeners		# Stiffeners		# Stiffeners		# Stiffeners	# Stiffeners	for MAESTRO										
11	28" centers		26" centers		24" centers		22" centers												
12	@ROUNDDOWN(V12)	+O12/26	@ROUNDDOWN(X12)	+O12/24	@ROUNDDOWN(Z12)	+O12/22	@ROUNDDOWN(AB12)	5	0	0.4375	5.69	0.17	3.94	0.215	!	WD1	Detail Design	+AD12	+L89
13	@ROUNDDOWN(V13)	+O13/26	@ROUNDDOWN(X13)	+O13/24	@ROUNDDOWN(Z13)	+O13/22	@ROUNDDOWN(AB13)	4	0	0.4375	5.69	0.17	3.94	0.215	!	WD2	Detail Design	+AD13	+L90
14	@ROUNDDOWN(V14)	+O14/26	@ROUNDDOWN(X14)	+O14/24	@ROUNDDOWN(Z14)	+O14/22	@ROUNDDOWN(AB14)	4	0	0.4375	5.69	0.17	3.94	0.215	!	WD3	Detail Design	+AD14	+L91
15	@ROUNDDOWN(V15)	+O15/26	@ROUNDDOWN(X15)	+O15/24	@ROUNDDOWN(Z15)	+O15/22	@ROUNDDOWN(AB15)	4	0	0.5	5.77	0.2	3.97	0.225	!	SS1	Detail Design	+AD15	+L92
16	@ROUNDDOWN(V16)	+O16/26	@ROUNDDOWN(X16)	+O16/24	@ROUNDDOWN(Z16)	+O16/22	@ROUNDDOWN(AB16)	0	0	0.4375	7.69	0.17	3.94	0.205	!	SS2	Detail Design	+AD16	+L93
17	@ROUNDDOWN(V17+V	+O17/26	@ROUNDDOWN(X17+X1	+O17/24	@ROUNDDOWN(Z17+Z1	+O17/22	@ROUNDDOWN(AB17+A	4	0	0.4375	7.69	0.17	3.94	0.205	!	SS3	Detail Design	+AD17	+L94
18	@ROUNDDOWN(V18)	+O18/26	@ROUNDDOWN(X18)	+O18/24	@ROUNDDOWN(Z18)	+O18/22	@ROUNDDOWN(AB18)	4	0	0.375	9.66	0.19	3.96	0.225	!	SS4	Detail Design	+AD18	+L95
19	@ROUNDDOWN(V19)	+O19/26	@ROUNDDOWN(X19)	+O19/24	@ROUNDDOWN(Z19)	+O19/22	@ROUNDDOWN(AB19)	4	0	0.4375	9.66	0.19	3.96	0.225	!	SS5	Detail Design	+AD19	+L96
20	@ROUNDDOWN(V20)	+O20/26	@ROUNDDOWN(X20)	+O20/24	@ROUNDDOWN(Z20)	+O20/22	@ROUNDDOWN(AB20)	0	0	0.4375	11.7	0.2	3.97	0.225	!	BS1	Detail Design	+AD20	+L97
21	@ROUNDDOWN(V21)	+O21/26	@ROUNDDOWN(X21)	+O21/24	@ROUNDDOWN(Z21)	+O21/22	@ROUNDDOWN(AB21)	1	0	0.4375	11.7	0.2	3.97	0.225	!	BS2	Detail Design	+AD21	+L98
22	@ROUNDDOWN(V22)	+O22/26	@ROUNDDOWN(X22)	+O22/24	@ROUNDDOWN(Z22)	+O22/22	@ROUNDDOWN(AB22)	2	0	0.5	11.7	0.2	3.97	0.225	!	BS3	Detail Design	+AD22	+L99
23	@ROUNDDOWN(V23)	+O23/26	@ROUNDDOWN(X23)	+O23/24	@ROUNDDOWN(Z23)	+O23/22	@ROUNDDOWN(AB23)	2	0	0.5	11.7	0.22	3.99	0.265	!	BS4	Detail Design	+AD23	+L100
24	@ROUNDDOWN(V24)	+O24/26	@ROUNDDOWN(X24)	+O24/24	@ROUNDDOWN(Z24)	+O24/22	@ROUNDDOWN(AB24)	1	0	0.75	11.7	0.22	3.99	0.265	!	BS5	Detail Design	+AD24	+L101
25	@ROUNDDOWN(V25)	+O25/26	@ROUNDDOWN(X25)	+O25/24	@ROUNDDOWN(Z25)	+O25/22	@ROUNDDOWN(AB25)	1	0	0.4375	11.7	0.2	3.97	0.225	!	IB1	Detail Design	+AD25	+L102
26	@ROUNDDOWN(V26)	+O26/26	@ROUNDDOWN(X26)	+O26/24	@ROUNDDOWN(Z26)	+O26/22	@ROUNDDOWN(AB26)	0	0	0.4375	11.7	0.2	3.97	0.225	!	IB2	Detail Design	+AD26	+L103
27	@ROUNDDOWN(V27)	+O27/26	@ROUNDDOWN(X27)	+O27/24	@ROUNDDOWN(Z27)	+O27/22	@ROUNDDOWN(AB27)	1	0	0.4375	11.7	0.2	3.97	0.225	!	IB3	Detail Design	+AD27	+L104
28	@ROUNDDOWN(V28)	+O28/26	@ROUNDDOWN(X28)	+O28/24	@ROUNDDOWN(Z28)	+O28/22	@ROUNDDOWN(AB28)	2	0	0.4375	11.7	0.2	3.97	0.225	!	IB4	Detail Design	+AD28	+L105
29	@ROUNDDOWN(V29)	+O29/26	@ROUNDDOWN(X29)	+O29/24	@ROUNDDOWN(Z29)	+O29/22	@ROUNDDOWN(AB29)	1	0	0.4375	11.7	0.2	3.97	0.225	!	IB5	Detail Design	+AD29	+L106
30	@ROUNDDOWN(V30)	+O30/26	@ROUNDDOWN(X30)	+O30/24	@ROUNDDOWN(Z30)	+O30/22	@ROUNDDOWN(AB30)	4	0	0.3125	4.73	0.19	3.96	0.21	!	ID1-1	Detail Design	+AD30	+L107
31	@ROUNDDOWN(V31)	+O31/26	@ROUNDDOWN(X31)	+O31/24	@ROUNDDOWN(Z31)	+O31/22	@ROUNDDOWN(AB31)	5	0	0.3125	4.73	0.19	3.96	0.21	!	ID1-2	Detail Design	+AD31	+L108
32	@ROUNDDOWN(V32)	+O32/26	@ROUNDDOWN(X32)	+O32/24	@ROUNDDOWN(Z32)	+O32/22	@ROUNDDOWN(AB32)	3	0	0.3125	4.73	0.19	3.96	0.21	!	ID1-3	Detail Design	+AD32	+L109
33	@ROUNDDOWN(V33)	+O33/26	@ROUNDDOWN(X33)	+O33/24	@ROUNDDOWN(Z33)	+O33/22	@ROUNDDOWN(AB33)	4	0	0.3125	5.77	0.2	3.97	0.225	!	ID2-1	Detail Design	+AD33	+L110
34	@ROUNDDOWN(V34)	+O34/26	@ROUNDDOWN(X34)	+O34/24	@ROUNDDOWN(Z34)	+O34/22	@ROUNDDOWN(AB34)	5	0	0.3125	5.77	0.2	3.97	0.225	!	ID2-2	Detail Design	+AD34	+L111
35	@ROUNDDOWN(V35)	+O35/26	@ROUNDDOWN(X35)	+O35/24	@ROUNDDOWN(Z35)	+O35/22	@ROUNDDOWN(AB35)	3	0	0.3125	5.77	0.2	3.97	0.225	!	ID2-3	Detail Design	+AD35	+L112
36	@ROUNDDOWN(V36)	+O36/26	@ROUNDDOWN(X36)	+O36/24	@ROUNDDOWN(Z36)	+O36/22	@ROUNDDOWN(AB36)	4	0	0.3125	7.69	0.17	3.94	0.205	!	ID3-1	Detail Design	+AD36	+L113
37	@ROUNDDOWN(V37)	+O37/26	@ROUNDDOWN(X37)	+O37/24	@ROUNDDOWN(Z37)	+O37/22	@ROUNDDOWN(AB37)	7	0	0.3125	7.69	0.17	3.94	0.205	!	ID3-2	Detail Design	+AD37	+L114
38	@ROUNDDOWN(V38)	+O38/26	@ROUNDDOWN(X38)	+O38/24	@ROUNDDOWN(Z38)	+O38/22	@ROUNDDOWN(AB38)	4	0	0.3125	7.69	0.17	3.94	0.205	!	ID4-1	Detail Design	+AD38	+L115
39	@ROUNDDOWN(V39)	+O39/26	@ROUNDDOWN(X39)	+O39/24	@ROUNDDOWN(Z39)	+O39/22	@ROUNDDOWN(AB39)	6	0	0.3125	7.69	0.17	3.94	0.205	!	ID4-2	Detail Design	+AD39	+L116
40	@ROUNDDOWN(V40)	+O40/26	@ROUNDDOWN(X40)	+O40/24	@ROUNDDOWN(Z40)	+O40/22	@ROUNDDOWN(AB40)	1	0	0.5	11.7	0.22	3.99	0.265	!	F-1	Detail Design	1	+Q1671
41	@ROUNDDOWN(V41)	+O41/26	@ROUNDDOWN(X41)	+O41/24	@ROUNDDOWN(Z41)	+O41/22	@ROUNDDOWN(AB41)	1	0	0.4375	11.7	0.22	3.99	0.265	!	F-2	Detail Design	1	+Q1672
42	@ROUNDDOWN(V42)	+O42/26	@ROUNDDOWN(X42)	+O42/24	@ROUNDDOWN(Z42)	+O42/22	@ROUNDDOWN(AB42)	1	0	0.4375	11.7	0.22	3.99	0.265	!	F-3	Detail Design	1	+Q1673
43	@ROUNDDOWN(V43)	+O43/26	@ROUNDDOWN(X43)	+O43/24	@ROUNDDOWN(Z43)	+O43/22	@ROUNDDOWN(AB43)	1	0	0.4375	11.7	0.22	3.99	0.265	!	F-4	Detail Design	1	+Q1674
44								1	n/a	0	17.3	0.15	3	0.425	!	O1 (half)	Detail Design	1	+Q1654
45								1	n/a	0	17.4	0.36	7.495	0.57	!	G2	Detail Design	1	+Q1655
46								1	n/a	0	17.4	0.36	7.495	0.57	!	O3	Detail Design	1	+Q1656
47								1	n/a	0	17.3	0.15	3	0.425	!	O20 (half)	Detail Design	1	+Q1657
48								1	n/a	0	17.4	0.36	7.495	0.57	!	O21	Detail Design	1	+Q1658
49								1	n/a	0	17.4	0.36	7.495	0.57	!	O22	Detail Design	1	+Q1659
50								1	n/a	0	17.3	0.15	3	0.425	!	O23 (half)	Detail Design	1	+Q1660
51								1	n/a	0	17.4	0.36	7.495	0.57	!	O24	Detail Design	1	+Q1661
52								1	n/a	0	17.4	0.36	7.495	0.57	!	G25	Detail Design	1	+Q1662
53								1	n/a	0	17.3	0.15	3	0.425	!	O26 (half)	Detail Design	1	+Q1663
54								1	n/a	0	17.4	0.36	7.495	0.57	!	O27	Detail Design	1	+Q1664
55								1	n/a	0	17.3	0.15	3	0.425	!	O28 (half)	Detail Design	1	+Q1665
56								1	n/a	0	17.4	0.36	7.495	0.57	!	O29	Detail Design	1	+Q1666
57																			

A	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE
1																
2																
3																
4																
5																
6								MAESTRG								
7			STIFFENER	FRAME				FRAME								
8			density is 0.283 lbf/in^3													
9	LINEAR ft	SQUARE ft	WEIGHT	HFW	TFW	BFF	TFF	HFW	TFW	BFF	TFF		SHAPE		Matl	LINEAR ft
10																
11																
12	+AD12*$A*$S	+AD12*$A*$S*(AG12+AI12)/12	12*$A*$S*AD12*(AG12*AH12+AI12*AJ12)*0.283	13.49	0.225	5.025	0.42	+AS12	+AT12	+AU12	+AV12	!		WD1	+AN97	+G12*$S/12
13	+AD13*$A*$S	+AD13*$A*$S*(AG13+AI13)/12	12*$A*$S*AD13*(AG13*AH13+AI13*AJ13)*0.283	13.49	0.225	5.025	0.42	+AS13	+AT13	+AU13	+AV13	!		WD2	+AN98	+G13*$S/12
14	+AD14*$A*$S	+AD14*$A*$S*(AG14+AI14)/12	12*$A*$S*AD14*(AG14*AH14+AI14*AJ14)*0.283	13.49	0.225	5.025	0.42	+AS14	+AT14	+AU14	+AV14	!		WD3	+AN99	+O14*$S/12
15	+AD15*$A*$S	+AD15*$A*$S*(AG15+AI15)/12	12*$A*$S*AD15*(AG15*AH15+AI15*AJ15)*0.283	13.405	0.23	5	0.335	+AS15	+AT15	+AU15	+AV15	!		SS1	3	+G15*$S/12
16	+AD16*$A*$S	+AD16*$A*$S*(AG16+AI16)/12	12*$A*$S*AD16*(AG16*AH16+AI16*AJ16)*0.283	13.405	0.23	5	0.335	+AS16	+AT16	+AU16	+AV16	!		SS2	+AN90	+G16*$S/12
17	+AD17*$A*$S	+AD17*$A*$S*(AG17+AI17)/12	12*$A*$S*AD17*(AG17*AH17+AI17*AJ17)*0.283	13.405	0.23	5	0.335	+AS17	+AT17	+AU17	+AV17	!		SS3	+AN90	+O17*$S/12
18	+AD18*$A*$S	+AD18*$A*$S*(AG18+AI18)/12	12*$A*$S*AD18*(AG18*AH18+AI18*AJ18)*0.283	13.49	0.225	5.025	0.42	+AS18	+AT18	+AU18	+AV18	!		SS4	+AN91	+O18*$S/12
19	+AD19*$A*$S	+AD19*$A*$S*(AG19+AI19)/12	12*$A*$S*AD19*(AG19*AH19+AI19*AJ19)*0.283	13.49	0.225	5.025	0.42	+AS19	+AT19	+AU19	+AV19	!		SS5	+AN92	+O19*$S/12
20	+AD20*$A*$S	+AD20*$A*$S*(AG20+AI20)/12	12*$A*$S*AD20*(AG20*AH20+AI20*AJ20)*0.283	15.43	0.295	6.99	0.43	+AS20	+AT20	+AU20	+AV20	!		BS1		+O20*$S/12
21	+AD21*$A*$S	+AD21*$A*$S*(AG21+AI21)/12	12*$A*$S*AD21*(AG21*AH21+AI21*AJ21)*0.283	0	0	0	0	+AS21-AS21	+AT21-AT21	+AU21-AU21	+AV21-AV21	!	floor	BS2		+G21*$S/12
22	+AD22*$A*$S	+AD22*$A*$S*(AG22+AI22)/12	12*$A*$S*AD22*(AG22*AH22+AI22*AJ22)*0.283	0	0	0	0	+AS22-AS22	+AT22-AT22	+AU22-AU22	+AV22-AV22	!	floor	BS3		+G22*$S/12
23	+AD23*$A*$S	+AD23*$A*$S*(AG23+AI23)/12	12*$A*$S*AD23*(AG23*AH23+AI23*AJ23)*0.283	0	0	0	0	+AS23-AS23	+AT23-AT23	+AU23-AU23	+AV23-AV23	!	floor	BS4		+G23*$S/12
24	+AD24*$A*$S	+AD24*$A*$S*(AG24+AI24)/12	12*$A*$S*AD24*(AG24*AH24+AI24*AJ24)*0.283	0	0	0	0	+AS24-AS24	+AT24-AT24	+AU24-AU24	+AV24-AV24	!	floor	BS5		+G24*$S/12
25	+AD25*$A*$S	+AD25*$A*$S*(AG25+AI25)/12	12*$A*$S*AD25*(AG25*AH25+AI25*AJ25)*0.283	0	0	0	0	+AS25	+AT25	+AU25	+AV25	!	none	IB1		+G25*$S/12
26	+AD26*$A*$S	+AD26*$A*$S*(AG26+AI26)/12	12*$A*$S*AD26*(AG26*AH26+AI26*AJ26)*0.283	0	0	0	0	+AS26	+AT26	+AU26	+AV26	!	none	IB2		+G26*$S/12
27	+AD27*$A*$S	+AD27*$A*$S*(AG27+AI27)/12	12*$A*$S*AD27*(AG27*AH27+AI27*AJ27)*0.283	0	0	0	0	+AS27	+AT27	+AU27	+AV27	!	none	IB3		+O27*$S/12
28	+AD28*$A*$S	+AD28*$A*$S*(AG28+AI28)/12	12*$A*$S*AD28*(AG28*AH28+AI28*AJ28)*0.283	0	0	0	0	+AS28	+AT28	+AU28	+AV28	!	none	IB4		+G28*$S/12
29	+AD29*$A*$S	+AD29*$A*$S*(AG29+AI29)/12	12*$A*$S*AD29*(AG29*AH29+AI29*AJ29)*0.283	0	0	0	0	+AS29	+AT29	+AU29	+AV29	!	none	IB5		+G29*$S/12
30	+AD30*$A*$S	+AD30*$A*$S*(AG30+AI30)/12	12*$A*$S*AD30*(AG30*AH30+AI30*AJ30)*0.283	11.84	0.23	6.49	0.38	+AS30	+AT30	+AU30	+AV30	!		ID1-1	+AN100	+G30*$S/12
31	+AD31*$A*$S	+AD31*$A*$S*(AG31+AI31)/12	12*$A*$S*AD31*(AG31*AH31+AI31*AJ31)*0.283	11.84	0.23	6.49	0.38	+AS31	+AT31	+AU31	+AV31	!		ID1-2	+AN101	+G31*$S/12
32	+AD32*$A*$S	+AD32*$A*$S*(AG32+AI32)/12	12*$A*$S*AD32*(AG32*AH32+AI32*AJ32)*0.283	11.84	0.23	6.49	0.38	+AS32	+AT32	+AU32	+AV32	!		ID1-3	+AN102	+G32*$S/12
33	+AD33*$A*$S	+AD33*$A*$S*(AG33+AI33)/12	12*$A*$S*AD33*(AG33*AH33+AI33*AJ33)*0.283	11.84	0.23	6.49	0.38	+AS33	+AT33	+AU33	+AV33	!		ID2-1	+AN103	+G33*$S/12
34	+AD34*$A*$S	+AD34*$A*$S*(AG34+AI34)/12	12*$A*$S*AD34*(AG34*AH34+AI34*AJ34)*0.283	11.84	0.23	6.49	0.38	+AS34	+AT34	+AU34	+AV34	!		ID2-2	+AN104	+G34*$S/12
35	+AD35*$A*$S	+AD35*$A*$S*(AG35+AI35)/12	12*$A*$S*AD35*(AG35*AH35+AI35*AJ35)*0.283	11.84	0.23	6.49	0.38	+AS35	+AT35	+AU35	+AV35	!		ID2-3	+AN105	+G35*$S/12
36	+AD36*$A*$S	+AD36*$A*$S*(AG36+AI36)/12	12*$A*$S*AD36*(AG36*AH36+AI36*AJ36)*0.283	11.84	0.23	6.49	0.38	+AS36	+AT36	+AU36	+AV36	!		ID3-1	+AN106	+G36*$S/12
37	+AD37*$A*$S	+AD37*$A*$S*(AG37+AI37)/12	12*$A*$S*AD37*(AG37*AH37+AI37*AJ37)*0.283	11.84	0.23	6.49	0.38	+AS37	+AT37	+AU37	+AV37	!		ID3-2	+AN107	+G37*$S/12
38	+AD38*$A*$S	+AD38*$A*$S*(AG38+AI38)/12	12*$A*$S*AD38*(AG38*AH38+AI38*AJ38)*0.283	11.84	0.23	6.49	0.38	+AS38	+AT38	+AU38	+AV38	!		ID4-1	+AN108	+G38*$S/12
39	+AD39*$A*$S	+AD39*$A*$S*(AG39+AI39)/12	12*$A*$S*AD39*(AG39*AH39+AI39*AJ39)*0.283	11.84	0.23	6.49	0.38	+AS39	+AT39	+AU39	+AV39	!		ID4-2	+AN109	+G39*$S/12
40	+AD40*$A*$S	+AD40*$A*$S*(AG40+AI40)/12	12*$A*$S*AD40*(AG40*AH40+AI40*AJ40)*0.283	n/a	n/a	n/a	n/a	0	0	0	0	!	none	F-1		+G40*$S/12
41	+AD41*$A*$S	+AD41*$A*$S*(AG41+AI41)/12	12*$A*$S*AD41*(AG41*AH41+AI41*AJ41)*0.283	n/a	n/a	n/a	n/a	0	0	0	0	!	none	F-2		+G41*$S/12
42	+AD42*$A*$S	+AD42*$A*$S*(AG42+AI42)/12	12*$A*$S*AD42*(AG42*AH42+AI42*AJ42)*0.283	n/a	n/a	n/a	n/a	0	0	0	0	!	none	F-3		+O42*$S/12
43	+AD43*$A*$S	+AD43*$A*$S*(AG43+AI43)/12	12*$A*$S*AD43*(AG43*AH43+AI43*AJ43)*0.283	n/a	n/a	n/a	n/a	0	0	0	0	!	none	F-4		+G43*$S/12
44	+AD44*$A*$S	+AD44*$A*$S*(AG44+AI44)/12	12*$A*$S*AD44*(AG44*AH44+AI44*AJ44)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G1 (half)	n/a	+O44*$S/12
45	+AD45*$A*$S	+AD45*$A*$S*(AG45+AI45)/12	12*$A*$S*AD45*(AG45*AH45+AI45*AJ45)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G2	n/a	+G45*$S/12
46	+AD46*$A*$S	+AD46*$A*$S*(AG46+AI46)/12	12*$A*$S*AD46*(AG46*AH46+AI46*AJ46)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G3	n/a	+G46*$S/12
47	+AD47*$A*$S	+AD47*$A*$S*(AG47+AI47)/12	12*$A*$S*AD47*(AG47*AH47+AI47*AJ47)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G20 (half)	n/a	+G47*$S/12
48	+AD48*$A*$S	+AD48*$A*$S*(AG48+AI48)/12	12*$A*$S*AD48*(AG48*AH48+AI48*AJ48)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G21	n/a	+O48*$S/12
49	+AD49*$A*$S	+AD49*$A*$S*(AG49+AI49)/12	12*$A*$S*AD49*(AG49*AH49+AI49*AJ49)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G22	n/a	+G49*$S/12
50	+AD50*$A*$S	+AD50*$A*$S*(AG50+AI50)/12	12*$A*$S*AD50*(AG50*AH50+AI50*AJ50)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G23 (half)	n/a	+G50*$S/12
51	+AD51*$A*$S	+AD51*$A*$S*(AG51+AI51)/12	12*$A*$S*AD51*(AG51*AH51+AI51*AJ51)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G24	n/a	+G51*$S/12
52	+AD52*$A*$S	+AD52*$A*$S*(AG52+AI52)/12	12*$A*$S*AD52*(AG52*AH52+AI52*AJ52)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G25	n/a	+O52*$S/12
53	+AD53*$A*$S	+AD53*$A*$S*(AG53+AI53)/12	12*$A*$S*AD53*(AG53*AH53+AI53*AJ53)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G26 (half)	n/a	+O53*$S/12
54	+AD54*$A*$S	+AD54*$A*$S*(AG54+AI54)/12	12*$A*$S*AD54*(AG54*AH54+AI54*AJ54)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G27	n/a	+G54*$S/12
55	+AD55*$A*$S	+AD55*$A*$S*(AG55+AI55)/12	12*$A*$S*AD55*(AG55*AH55+AI55*AJ55)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G28 (half)	n/a	+G55*$S/12
56	+AD56*$A*$S	+AD56*$A*$S*(AG56+AI56)/12	12*$A*$S*AD56*(AG56*AH56+AI56*AJ56)*0.283	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	G29	n/a	+G56*$S/12
57	@SUM(AP56..AP12)	@SUM(AQ56..AQ12)	@SUM(AR56..AR12)													@SUM(BE56..BE12)

A	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS
1												"NUM" different scantlings=		
2												# stiffeners	7	
3												# frames	10	
4												# girders	5	
5						ORIEN	FLAT=1	VERT	OVHD=3			# plates	8	
6								SHAPE.	FLAT=1	CURVE=2			@SUM(BR2..BR5)	
7		FRAME	Plate			ASSEM	ERECTION					Matl Rec&Prep		Matl Rec&Prep
8									Plate			(SStage=1)		(SStage=1)
9	SQUARE ft	WEIGHT	PMatl	B(m)	Edges	ORIEN	ORIENT	SHAPE	LINEAR ft	SQUARE ft	WEIGHT			
10														
11														
12	+$S*O12/12*(AS12+AU12)/12	+$S*O12*(AS12*AT12+AU12*AV12)*0.283	3	+O12	2	1	1	2	+BJ12*$A*$S	+O12/12*$A*$S	+BO12*12^2*AF12*0.283	+AQ12+BF12+BO12	1	0.01*BQ12*(0.35+0.65*$NUM/30)
13	+$S*O13/12*(AS13+AU13)/12	+$S*O13*(AS13*AT13+AU13*AV13)*0.283	3	+O13	1	1	1	2	+BJ13*$A*$S	+O13/12*$A*$S	+BO13*12^2*AF13*0.283	+AQ13+BF13+BO13	1	0.01*BQ13*(0.35+0.65*$NUM/30)
14	+$S*O14/12*(AS14+AU14)/12	+$S*O14*(AS14*AT14+AU14*AV14)*0.283	3	+O14	1	1	1	2	+BJ14*$A*$S	+O14/12*$A*$S	+BO14*12^2*AF14*0.283	+AQ14+BF14+BO14	1	0.01*BQ14*(0.35+0.65*$NUM/30)
15	+$S*O15/12*(AS15+AU15)/12	+$S*O15*(AS15*AT15+AU15*AV15)*0.283	3	+O15	1	1	2	2	+BJ15*$A*$S	+O15/12*$A*$S	+BO15*12^2*AF15*0.283	+AQ15+BF15+BO15	1	0.01*BQ15*(0.35+0.65*$NUM/30)
16	+$S*O16/12*(AS16+AU16)/12	+$S*O16*(AS16*AT16+AU16*AV16)*0.283	2	+O16	0	1	2	2	+BJ16*$A*$S	+O16/12*$A*$S	+BO16*12^2*AF16*0.283	+AQ16+BF16+BO16	1	0.01*BQ16*(0.35+0.65*$NUM/30)
17	+$S*O17/12*(AS17+AU17)/12	+$S*O17*(AS17*AT17+AU17*AV17)*0.283	2	+O17	1	1	2	2	+BJ17*$A*$S	+O17/12*$A*$S	+BO17*12^2*AF17*0.283	+AQ17+BF17+BO17	1	0.01*BQ17*(0.35+0.65*$NUM/30)
18	+$S*O18/12*(AS18+AU18)/12	+$S*O18*(AS18*AT18+AU18*AV18)*0.283	2	+O18	1	1	2	2	+BJ18*$A*$S	+O18/12*$A*$S	+BO18*12^2*AF18*0.283	+AQ18+BF18+BO18	1	0.01*BQ18*(0.35+0.65*$NUM/30)
19	+$S*O19/12*(AS19+AU19)/12	+$S*O19*(AS19*AT19+AU19*AV19)*0.283	2	+O19	2	1	2	2	+BJ19*$A*$S	+O19/12*$A*$S	+BO19*12^2*AF19*0.283	+AQ19+BF19+BO19	1	0.01*BQ19*(0.35+0.65*$NUM/30)
20	+$S*O20/12*(AS20+AU20)/12	+$S*O20*(AS20*AT20+AU20*AV20)*0.283	2	+O20	0	1	1	2	+BJ20*$A*$S	+O20/12*$A*$S	+BO20*12^2*AF20*0.283	+AQ20+BF20+BO20	1	0.01*BQ20*(0.35+0.65*$NUM/30)
21	+$S*O21/12*(AS21+AU21)/12	+$S*O21*(AS21*AT21+AU21*AV21)*0.283	2	+O21	0	1	1	2	+BJ21*$A*$S	+O21/12*$A*$S	+BO21*12^2*AF21*0.283	+AQ21+BF21+BO21	1	0.01*BQ21*(0.35+0.65*$NUM/30)
22	+$S*O22/12*(AS22+AU22)/12	+$S*O22*(AS22*AT22+AU22*AV22)*0.283	2	+O22	1	1	1	2	+BJ22*$A*$S	+O22/12*$A*$S	+BO22*12^2*AF22*0.283	+AQ22+BF22+BO22	1	0.01*BQ22*(0.35+0.65*$NUM/30)
23	+$S*O23/12*(AS23+AU23)/12	+$S*O23*(AS23*AT23+AU23*AV23)*0.283	2	+O23	1	1	1	2	+BJ23*$A*$S	+O23/12*$A*$S	+BO23*12^2*AF23*0.283	+AQ23+BF23+BO23	1	0.01*BQ23*(0.35+0.65*$NUM/30)
24	+$S*O24/12*(AS24+AU24)/12	+$S*O24*(AS24*AT24+AU24*AV24)*0.283	2	+O24	1	1	1	1	+BJ24*$A*$S	+O24/12*$A*$S	+BO24*12^2*AF24*0.283	+AQ24+BF24+BO24	1	0.01*BQ24*(0.35+0.65*$NUM/30)
25	+$S*O25/12*(AS25+AU25)/12	+$S*O25*(AS25*AT25+AU25*AV25)*0.283	2	+O25	1	1	1	1	+BJ25*$A*$S	+O25/12*$A*$S	+BO25*12^2*AF25*0.283	+AQ25+BF25+BO25	1	0.01*BQ25*(0.35+0.65*$NUM/30)
26	+$S*O26/12*(AS26+AU26)/12	+$S*O26*(AS26*AT26+AU26*AV26)*0.283	2	+O26	1	1	1	1	+BJ26*$A*$S	+O26/12*$A*$S	+BO26*12^2*AF26*0.283	+AQ26+BF26+BO26	1	0.01*BQ26*(0.35+0.65*$NUM/30)
27	+$S*O27/12*(AS27+AU27)/12	+$S*O27*(AS27*AT27+AU27*AV27)*0.283	2	+O27	1	1	1	1	+BJ27*$A*$S	+O27/12*$A*$S	+BO27*12^2*AF27*0.283	+AQ27+BF27+BO27	1	0.01*BQ27*(0.35+0.65*$NUM/30)
28	+$S*O28/12*(AS28+AU28)/12	+$S*O28*(AS28*AT28+AU28*AV28)*0.283	2	+O28	0	1	1	1	+BJ28*$A*$S	+O28/12*$A*$S	+BO28*12^2*AF28*0.283	+AQ28+BF28+BO28	1	0.01*BQ28*(0.35+0.65*$NUM/30)
29	+$S*O29/12*(AS29+AU29)/12	+$S*O29*(AS29*AT29+AU29*AV29)*0.283	2	+O29	0	1	1	1	+BJ29*$A*$S	+O29/12*$A*$S	+BO29*12^2*AF29*0.283	+AQ29+BF29+BO29	1	0.01*BQ29*(0.35+0.65*$NUM/30)
30	+$S*O30/12*(AS30+AU30)/12	+$S*O30*(AS30*AT30+AU30*AV30)*0.283	2	+O30	0	1	1	1	+BJ30*$A*$S	+O30/12*$A*$S	+BO30*12^2*AF30*0.283	+AQ30+BF30+BO30	1	0.01*BQ30*(0.35+0.65*$NUM/30)
31	+$S*O31/12*(AS31+AU31)/12	+$S*O31*(AS31*AT31+AU31*AV31)*0.283	2	+O31	1	1	1	1	+BJ31*$A*$S	+O31/12*$A*$S	+BO31*12^2*AF31*0.283	+AQ31+BF31+BO31	1	0.01*BQ31*(0.35+0.65*$NUM/30)
32	+$S*O32/12*(AS32+AU32)/12	+$S*O32*(AS32*AT32+AU32*AV32)*0.283	2	+O32	2	1	1	1	+BJ32*$A*$S	+O32/12*$A*$S	+BO32*12^2*AF32*0.283	+AQ32+BF32+BO32	1	0.01*BQ32*(0.35+0.65*$NUM/30)
33	+$S*O33/12*(AS33+AU33)/12	+$S*O33*(AS33*AT33+AU33*AV33)*0.283	2	+O33	0	1	1	1	+BJ33*$A*$S	+O33/12*$A*$S	+BO33*12^2*AF33*0.283	+AQ33+BF33+BO33	1	0.01*BQ33*(0.35+0.65*$NUM/30)
34	+$S*O34/12*(AS34+AU34)/12	+$S*O34*(AS34*AT34+AU34*AV34)*0.283	2	+O34	0	1	1	1	+BJ34*$A*$S	+O34/12*$A*$S	+BO34*12^2*AF34*0.283	+AQ34+BF34+BO34	1	0.01*BQ34*(0.35+0.65*$NUM/30)
35	+$S*O35/12*(AS35+AU35)/12	+$S*O35*(AS35*AT35+AU35*AV35)*0.283	2	+O35	0	1	1	1	+BJ35*$A*$S	+O35/12*$A*$S	+BO35*12^2*AF35*0.283	+AQ35+BF35+BO35	1	0.01*BQ35*(0.35+0.65*$NUM/30)
36	+$S*O36/12*(AS36+AU36)/12	+$S*O36*(AS36*AT36+AU36*AV36)*0.283	2	+O36	0	1	1	1	+BJ36*$A*$S	+O36/12*$A*$S	+BO36*12^2*AF36*0.283	+AQ36+BF36+BO36	1	0.01*BQ36*(0.35+0.65*$NUM/30)
37	+$S*O37/12*(AS37+AU37)/12	+$S*O37*(AS37*AT37+AU37*AV37)*0.283	2	+O37	0	1	1	1	+BJ37*$A*$S	+O37/12*$A*$S	+BO37*12^2*AF37*0.283	+AQ37+BF37+BO37	1	0.01*BQ37*(0.35+0.65*$NUM/30)
38	+$S*O38/12*(AS38+AU38)/12	+$S*O38*(AS38*AT38+AU38*AV38)*0.283	2	+O38	0	1	1	1	+BJ38*$A*$S	+O38/12*$A*$S	+BO38*12^2*AF38*0.283	+AQ38+BF38+BO38	1	0.01*BQ38*(0.35+0.65*$NUM/30)
39	+$S*O39/12*(AS39+AU39)/12	+$S*O39*(AS39*AT39+AU39*AV39)*0.283	2	+O39	0	1	1	1	+BJ39*$A*$S	+O39/12*$A*$S	+BO39*12^2*AF39*0.283	+AQ39+BF39+BO39	1	0.01*BQ39*(0.35+0.65*$NUM/30)
40	+$S*O40/12*(AS40+AU40)/12	+$S*O40*(AS40*AT40+AU40*AV40)*0.283	2	+O40	2	1	2	1	+BJ40*$A*$S	+O40/12*$A*$S	+BO40*12^2*AF40*0.283	+AQ40+BF40+BO40	1	0.01*BQ40*(0.35+0.65*$NUM/30)
41	+$S*O41/12*(AS41+AU41)/12	+$S*O41*(AS41*AT41+AU41*AV41)*0.283	2	+O41	2	1	2	1	+BJ41*$A*$S	+O41/12*$A*$S	+BO41*12^2*AF41*0.283	+AQ41+BF41+BO41	1	0.01*BQ41*(0.35+0.65*$NUM/30)
42	+$S*O42/12*(AS42+AU42)/12	+$S*O42*(AS42*AT42+AU42*AV42)*0.283	2	+O42	2	1	2	1	+BJ42*$A*$S	+O42/12*$A*$S	+BO42*12^2*AF42*0.283	+AQ42+BF42+BO42	1	0.01*BQ42*(0.35+0.65*$NUM/30)
43	+$S*O43/12*(AS43+AU43)/12	+$S*O43*(AS43*AT43+AU43*AV43)*0.283	2	+O43	2	1	2	1	+BJ43*$A*$S	+O43/12*$A*$S	+BO43*12^2*AF43*0.283	+AQ43+BF43+BO43	1	0.01*BQ43*(0.35+0.65*$NUM/30)
44	+$S*O44/12*(AS44+AU44)/12	+$S*O44*(AS44*AT44+AU44*AV44)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ44+BF44+BO44	1	0.01*BQ44*(0.35+0.65*$NUM/30)
45	+$S*O45/12*(AS45+AU45)/12	+$S*O45*(AS45*AT45+AU45*AV45)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ45+BF45+BO45	1	0.01*BQ45*(0.35+0.65*$NUM/30)
46	+$S*O46/12*(AS46+AU46)/12	+$S*O46*(AS46*AT46+AU46*AV46)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ46+BF46+BO46	1	0.01*BQ46*(0.35+0.65*$NUM/30)
47	+$S*O47/12*(AS47+AU47)/12	+$S*O47*(AS47*AT47+AU47*AV47)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ47+BF47+BO47	1	0.01*BQ47*(0.35+0.65*$NUM/30)
48	+$S*O48/12*(AS48+AU48)/12	+$S*O48*(AS48*AT48+AU48*AV48)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ48+BF48+BO48	1	0.01*BQ48*(0.35+0.65*$NUM/30)
49	+$S*O49/12*(AS49+AU49)/12	+$S*O49*(AS49*AT49+AU49*AV49)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ49+BF49+BO49	1	0.01*BQ49*(0.35+0.65*$NUM/30)
50	+$S*O50/12*(AS50+AU50)/12	+$S*O50*(AS50*AT50+AU50*AV50)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ50+BF50+BO50	1	0.01*BQ50*(0.35+0.65*$NUM/30)
51	+$S*O51/12*(AS51+AU51)/12	+$S*O51*(AS51*AT51+AU51*AV51)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ51+BF51+BO51	1	0.01*BQ51*(0.35+0.65*$NUM/30)
52	+$S*O52/12*(AS52+AU52)/12	+$S*O52*(AS52*AT52+AU52*AV52)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ52+BF52+BO52	1	0.01*BQ52*(0.35+0.65*$NUM/30)
53	+$S*O53/12*(AS53+AU53)/12	+$S*O53*(AS53*AT53+AU53*AV53)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ53+BF53+BO53	1	0.01*BQ53*(0.35+0.65*$NUM/30)
54	+$S*O54/12*(AS54+AU54)/12	+$S*O54*(AS54*AT54+AU54*AV54)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ54+BF54+BO54	1	0.01*BQ54*(0.35+0.65*$NUM/30)
55	+$S*O55/12*(AS55+AU55)/12	+$S*O55*(AS55*AT55+AU55*AV55)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ55+BF55+BO55	1	0.01*BQ55*(0.35+0.65*$NUM/30)
56	+$S*O56/12*(AS56+AU56)/12	+$S*O56*(AS56*AT56+AU56*AV56)*0.283		n/a	n/a	1	1	1	n/a	n/a	n/a	+AQ56+BF56+BO56	1	0.01*BQ56*(0.35+0.65*$NUM/30)
57	@SUM(BF56 BF12)	@SUM(BG56 .BG12)							@SUM(BN56 .1	@SUM(BO56 B(	@SUM(BP56..BP12)			@SUM(BS56 .BS12)

A	BT	BU	BV	BW	BX	BY
1						
2						
3						
4						
5						
6						
7	Auto Flame Cut			Auto Flame Cut	Manl Flame Cut	
8	(SStage=1)	Auto ?	Stage	(SStage=1)	(SStage=2)	
9						
10						
11						
12	@IF(BU12=1,BN12,0)	1	1	@VLOOKUP($AF12,$A_ORIGINAL,1)*$BT12	@IF(BU12=0,BN12,0)+@IF(DW4="YES",2*AN12*(AG12+AI12)/12,AN12*(AG12+AI12))+$S*(AS12+AU12)/12+2*BI12/12	1
13	@IF(BU13=1,BN13,0)	1	1	@VLOOKUP($AF13,$A_ORIGINAL,1)*$BT13	@IF(BU13=0,BN13,0)+@IF(DW5="YES",2*AN13*(AG13+AI13)/12,AN13*(AG13+AI13))+$S*(AS13+AU13)/12+2*BI13/12	1
14	@IF(BU14=1,BN14,0)	1	1	@VLOOKUP($AF14,$A_ORIGINAL,1)*$BT14	@IF(BU14=0,BN14,0)+@IF(RATE="YES",2*AN14*(AG14+AI14)/12,AN14*(AG14+AI14))+$S*(AS14+AU14)/12+2*BI14/12	1
15	@IF(BU15=1,BN15,0)	1	1	@VLOOKUP($AF15,$A_ORIGINAL,1)*$BT15	@IF(BU15=0,BN15,0)+@IF(DW7="YES",2*AN15*(AG15+AI15)/12,AN15*(AG15+AI15))+$S*(AS15+AU15)/12+2*BI15/12	1
16	@IF(BU16=1,BN16,0)	1	1	@VLOOKUP($AF16,$A_ORIGINAL,1)*$BT16	@IF(BU16=0,BN16,0)+@IF(DW8="YES",2*AN16*(AG16+AI16)/12,AN16*(AG16+AI16))+$S*(AS16+AU16)/12+2*BI16/12	1
17	@IF(BU17=1,BN17,0)	1	1	@VLOOKUP($AF17,$A_ORIGINAL,1)*$BT17	@IF(BU17=0,BN17,0)+@IF(DW9="YES",2*AN17*(AG17+AI17)/12,AN17*(AG17+AI17))+$S*(AS17+AU17)/12+2*BI17/12	1
18	@IF(BU18=1,BN18,0)	1	1	@VLOOKUP($AF18,$A_ORIGINAL,1)*$BT18	@IF(BU18=0,BN18,0)+@IF(DW10="YES",2*AN18*(AG18+AI18)/12,AN18*(AG18+AI18))+$S*(AS18+AU18)/12+2*BI18/12	1
19	@IF(BU19=1,BN19,0)	1	1	@VLOOKUP($AF19,$A_ORIGINAL,1)*$BT19	@IF(BU19=0,BN19,0)+@IF(DW11="YES",2*AN19*(AG19+AI19)/12,AN19*(AG19+AI19))+$S*(AS19+AU19)/12+2*BI19/12	1
20	@IF(BU20=1,BN20,0)	1	1	@VLOOKUP($AF20,$A_ORIGINAL,1)*$BT20	@IF(BU20=0,BN20,0)+@IF(DW12="YES",2*AN20*(AG20+AI20)/12,AN20*(AG20+AI20))+$S*(AS20+AU20)/12+2*BI20/12	1
21	@IF(BU21=1,BN21,0)	1	1	@VLOOKUP($AF21,$A_ORIGINAL,1)*$BT21	@IF(BU21=0,BN21,0)+@IF(DW13="YES",2*AN21*(AG21+AI21)/12,AN21*(AG21+AI21))+$S*(AS21+AU21)/12+2*BI21/12	1
22	@IF(BU22=1,BN22,0)	1	1	@VLOOKUP($AF22,$A_ORIGINAL,1)*$BT22	@IF(BU22=0,BN22,0)+@IF(DW14="YES",2*AN22*(AG22+AI22)/12,AN22*(AG22+AI22))+$S*(AS22+AU22)/12+2*BI22/12	1
23	@IF(BU23=1,BN23,0)	1	1	@VLOOKUP($AF23,$A_ORIGINAL,1)*$BT23	@IF(BU23=0,BN23,0)+@IF(DW15="YES",2*AN23*(AG23+AI23)/12,AN23*(AG23+AI23))+$S*(AS23+AU23)/12+2*BI23/12	1
24	@IF(BU24=1,BN24,0)	1	1	@VLOOKUP($AF24,$A_ORIGINAL,1)*$BT24	@IF(BU24=0,BN24,0)+@IF(DW16="YES",2*AN24*(AG24+AI24)/12,AN24*(AG24+AI24))+$S*(AS24+AU24)/12+2*BI24/12	1
25	@IF(BU25=1,BN25+2*BE25,0)	1	1	@VLOOKUP($AF25,$A_ORIGINAL,1)*$BT25	@IF(BU25=0,BN25,0)+@IF(DW17="YES",2*AN25*(AG25+AI25)/12,AN25*(AG25+AI25))+$S*(AS25+AU25)/12+2*BI25/12	1
26	@IF(BU26=1,BN26+2*BE26,0)	1	1	@VLOOKUP($AF26,$A_ORIGINAL,1)*$BT26	@IF(BU26=0,BN26,0)+@IF(DW18="YES",2*AN26*(AG26+AI26)/12,AN26*(AG26+AI26))+$S*(AS26+AU26)/12+2*BI26/12	1
27	@IF(BU27=1,BN27+2*BE27,0)	1	1	@VLOOKUP($AF27,$A_ORIGINAL,1)*$BT27	@IF(BU27=0,BN27,0)+@IF(DW19="YES",2*AN27*(AG27+AI27)/12,AN27*(AG27+AI27))+$S*(AS27+AU27)/12+2*BI27/12	1
28	@IF(BU28=1,BN28+2*BE28,0)	1	1	@VLOOKUP($AF28,$A_ORIGINAL,1)*$BT28	@IF(BU28=0,BN28,0)+@IF(DW20="YES",2*AN28*(AG28+AI28)/12,AN28*(AG28+AI28))+$S*(AS28+AU28)/12+2*BI28/12	1
29	@IF(BU29=1,BN29+2*BE29,0)	1	1	@VLOOKUP($AF29,$A_ORIGINAL,1)*$BT29	@IF(BU29=0,BN29,0)+@IF(DW21="YES",2*AN29*(AG29+AI29)/12,AN29*(AG29+AI29))+$S*(AS29+AU29)/12+2*BI29/12	1
30	@IF(BU30=1,BN30,0)	1	1	@VLOOKUP($AF30,$A_ORIGINAL,1)*$BT30	@IF(BU30=0,BN30,0)+@IF(DW22="YES",2*AN30*(AG30+AI30)/12,AN30*(AG30+AI30))+$S*(AS30+AU30)/12+2*BI30/12	1
31	@IF(BU31=1,BN31,0)	1	1	@VLOOKUP($AF31,$A_ORIGINAL,1)*$BT31	@IF(BU31=0,BN31,0)+@IF(DW23="YES",2*AN31*(AG31+AI31)/12,AN31*(AG31+AI31))+$S*(AS31+AU31)/12+2*BI31/12	1
32	@IF(BU32=1,BN32,0)	1	1	@VLOOKUP($AF32,$A_ORIGINAL,1)*$BT32	@IF(BU32=0,BN32,0)+@IF(DW24="YES",2*AN32*(AG32+AI32)/12,AN32*(AG32+AI32))+$S*(AS32+AU32)/12+2*BI32/12	1
33	@IF(BU33=1,BN33,0)	1	1	@VLOOKUP($AF33,$A_ORIGINAL,1)*$BT33	@IF(BU33=0,BN33,0)+@IF(DW25="YES",2*AN33*(AG33+AI33)/12,AN33*(AG33+AI33))+$S*(AS33+AU33)/12+2*BI33/12	1
34	@IF(BU34=1,BN34,0)	1	1	@VLOOKUP($AF34,$A_ORIGINAL,1)*$BT34	@IF(BU34=0,BN34,0)+@IF(DW26="YES",2*AN34*(AG34+AI34)/12,AN34*(AG34+AI34))+$S*(AS34+AU34)/12+2*BI34/12	1
35	@IF(BU35=1,BN35,0)	1	1	@VLOOKUP($AF35,$A_ORIGINAL,1)*$BT35	@IF(BU35=0,BN35,0)+@IF(DW27="YES",2*AN35*(AG35+AI35)/12,AN35*(AG35+AI35))+$S*(AS35+AU35)/12+2*BI35/12	1
36	@IF(BU36=1,BN36,0)	1	1	@VLOOKUP($AF36,$A_ORIGINAL,1)*$BT36	@IF(BU36=0,BN36,0)+@IF(DW28="YES",2*AN36*(AG36+AI36)/12,AN36*(AG36+AI36))+$S*(AS36+AU36)/12+2*BI36/12	1
37	@IF(BU37=1,BN37,0)	1	1	@VLOOKUP($AF37,$A_ORIGINAL,1)*$BT37	@IF(BU37=0,BN37,0)+@IF(DW29="YES",2*AN37*(AG37+AI37)/12,AN37*(AG37+AI37))+$S*(AS37+AU37)/12+2*BI37/12	1
38	@IF(BU38=1,BN38,0)	1	1	@VLOOKUP($AF38,$A_ORIGINAL,1)*$BT38	@IF(BU38=0,BN38,0)+@IF(DW30="YES",2*AN38*(AG38+AI38)/12,AN38*(AG38+AI38))+$S*(AS38+AU38)/12+2*BI38/12	1
39	@IF(BU39=1,BN39,0)	1	1	@VLOOKUP($AF39,$A_ORIGINAL,1)*$BT39	@IF(BU39=0,BN39,0)+@IF(DW31="YES",2*AN39*(AG39+AI39)/12,AN39*(AG39+AI39))+$S*(AS39+AU39)/12+2*BI39/12	1
40	@IF(BU40=1,BN40+2*BE40,0)	1	1	@VLOOKUP($AF40,$A_ORIGINAL,1)*$BT40	@IF(BU40=0,BN40,0)+@IF(DW32="YES",2*AN40*(AG40+AI40)/12,AN40*(AG40+AI40))+$S*(AS40+AU40)/12+2*BI40/12	1
41	@IF(BU41=1,BN41+2*BE41,0)	1	1	@VLOOKUP($AF41,$A_ORIGINAL,1)*$BT41	@IF(BU41=0,BN41,0)+@IF(DW33="YES",2*AN41*(AG41+AI41)/12,AN41*(AG41+AI41))+$S*(AS41+AU41)/12+2*BI41/12	1
42	@IF(BU42=1,BN42+2*BE42,0)	1	1	@VLOOKUP($AF42,$A_ORIGINAL,1)*$BT42	@IF(BU42=0,BN42,0)+@IF(DW34="YES",2*AN42*(AG42+AI42)/12,AN42*(AG42+AI42))+$S*(AS42+AU42)/12+2*BI42/12	1
43	@IF(BU43=1,BN43+2*BE43,0)	1	1	@VLOOKUP($AF43,$A_ORIGINAL,1)*$BT43	@IF(BU43=0,BN43,0)+@IF(DW35="YES",2*AN43*(AG43+AI43)/12,AN43*(AG43+AI43))+$S*(AS43+AU43)/12+2*BI43/12	1
44	n/a	1	1	n/a	@IF(BU44=0,BN44,0)+@IF(DW36="YES",2*AN44*(AG44+AI44)/12,AN44*(AG44+AI44))+$S*(AS44+AU44)/12+2*BI44/12	1
45	n/a	1	1	n/a	@IF(BU45=0,BN45,0)+@IF(DW37="YES",2*AN45*(AG45+AI45)/12,AN45*(AG45+AI45))+$S*(AS45+AU45)/12+2*BI45/12	1
46	n/a	1	1	n/a	@IF(BU46=0,BN46,0)+@IF(DW38="YES",2*AN46*(AG46+AI46)/12,AN46*(AG46+AI46))+$S*(AS46+AU46)/12+2*BI46/12	1
47	n/a	1	1	n/a	@IF(BU47=0,BN47,0)+@IF(DW39="YES",2*AN47*(AG47+AI47)/12,AN47*(AG47+AI47))+$S*(AS47+AU47)/12+2*BI47/12	1
48	n/a	1	1	n/a	@IF(BU48=0,BN48,0)+@IF(DW40="YES",2*AN48*(AG48+AI48)/12,AN48*(AG48+AI48))+$S*(AS48+AU48)/12+2*BI48/12	1
49	n/a	1	1	n/a	@IF(BU49=0,BN49,0)+@IF(DW41="YES",2*AN49*(AG49+AI49)/12,AN49*(AG49+AI49))+$S*(AS49+AU49)/12+2*BI49/12	1
50	n/a	1	1	n/a	@IF(BU50=0,BN50,0)+@IF(DW42="YES",2*AN50*(AG50+AI50)/12,AN50*(AG50+AI50))+$S*(AS50+AU50)/12+2*BI50/12	1
51	n/a	1	1	n/a	@IF(BU51=0,BN51,0)+@IF(DW43="YES",2*AN51*(AG51+AI51)/12,AN51*(AG51+AI51))+$S*(AS51+AU51)/12+2*BI51/12	1
52	n/a	1	1	n/a	@IF(BU52=0,BN52,0)+@IF(DW44="YES",2*AN52*(AG52+AI52)/12,AN52*(AG52+AI52))+$S*(AS52+AU52)/12+2*BI52/12	1
53	n/a	1	1	n/a	@IF(BU53=0,BN53,0)+@IF(DW45="YES",2*AN53*(AG53+AI53)/12,AN53*(AG53+AI53))+$S*(AS53+AU53)/12+2*BI53/12	1
54	n/a	1	1	n/a	@IF(BU54=0,BN54,0)+@IF(DW46="YES",2*AN54*(AG54+AI54)/12,AN54*(AG54+AI54))+$S*(AS54+AU54)/12+2*BI54/12	1
55	n/a	1	1	n/a	@IF(BU55=0,BN55,0)+@IF(DW47="YES",2*AN55*(AG55+AI55)/12,AN55*(AG55+AI55))+$S*(AS55+AU55)/12+2*BI55/12	1
56	n/a	1	1	n/a	@IF(BU56=0,BN56,0)+@IF(DW48="YES",2*AN56*(AG56+AI56)/12,AN56*(AG56+AI56))+$S*(AS56+AU56)/12+2*BI56/12	1
57				@SUM(BW56. BW12)		

A	BZ	CA	CB	CC
1				
2				
3				
4				
5				
6				
7	Manl Flame Cut	Edge Prep Flat		Edge Prep Flat
8	(SStage=2)	(SStage=1)		(SStage=1)
9				
10				
11				
12	@VLOOKUP($AF12,$A_ORIGINAL,2)*$BX12	2*BN12+2*BI12+AP12+BE12+@IF(BL12=1,(AN12*(AG12+AI12)+S*(AS12+AU12))/12,0)	1	@VLOOKUP($AF12,$A_ORIGINAL,3)*$CA12
13	@VLOOKUP($AF13,$A_ORIGINAL,2)*$BX13	2*BN13+2*BI13+AP13+BE13+@IF(BL13=1,(AN13*(AG13+AI13)+S*(AS13+AU13))/12,0)	1	@VLOOKUP($AF13,$A_ORIGINAL,3)*$CA13
14	@VLOOKUP($AF14,$A_ORIGINAL,2)*$BX14	2*BN14+2*BI14+AP14+BE14+@IF(BL14=1,(AN14*(AG14+AI14)+S*(AS14+AU14))/12,0)	1	@VLOOKUP($AF14,$A_ORIGINAL,3)*$CA14
15	@VLOOKUP($AF15,$A_ORIGINAL,2)*$BX15	2*BN15+2*BI15+AP15+BE15+@IF(BL15=1,(AN15*(AG15+AI15)+S*(AS15+AU15))/12,0)	1	@VLOOKUP($AF15,$A_ORIGINAL,3)*$CA15
16	@VLOOKUP($AF16,$A_ORIGINAL,2)*$BX16	2*BN16+2*BI16+AP16+BE16+@IF(BL16=1,(AN16*(AG16+AI16)+S*(AS16+AU16))/12,0)	1	@VLOOKUP($AF16,$A_ORIGINAL,3)*$CA16
17	@VLOOKUP($AF17,$A_ORIGINAL,2)*$BX17	2*BN17+2*BI17+AP17+BE17+@IF(BL17=1,(AN17*(AG17+AI17)+S*(AS17+AU17))/12,0)	1	@VLOOKUP($AF17,$A_ORIGINAL,3)*$CA17
18	@VLOOKUP($AF18,$A_ORIGINAL,2)*$BX18	2*BN18+2*BI18+AP18+BE18+@IF(BL18=1,(AN18*(AG18+AI18)+S*(AS18+AU18))/12,0)	1	@VLOOKUP($AF18,$A_ORIGINAL,3)*$CA18
19	@VLOOKUP($AF19,$A_ORIGINAL,2)*$BX19	2*BN19+2*BI19+AP19+BE19+@IF(BL19=1,(AN19*(AG19+AI19)+S*(AS19+AU19))/12,0)	1	@VLOOKUP($AF19,$A_ORIGINAL,3)*$CA19
20	@VLOOKUP($AF20,$A_ORIGINAL,2)*$BX20	2*BN20+2*BI20+AP20+BE20+@IF(BL20=1,(AN20*(AG20+AI20)+S*(AS20+AU20))/12,0)	1	@VLOOKUP($AF20,$A_ORIGINAL,3)*$CA20
21	@VLOOKUP($AF21,$A_ORIGINAL,2)*$BX21	2*BN21+2*BI21+AP21+BE21+@IF(BL21=1,(AN21*(AG21+AI21)+S*(AS21+AU21))/12,0)	1	@VLOOKUP($AF21,$A_ORIGINAL,3)*$CA21
22	@VLOOKUP($AF22,$A_ORIGINAL,2)*$BX22	2*BN22+2*BI22+AP22+BE22+@IF(BL22=1,(AN22*(AG22+AI22)+S*(AS22+AU22))/12,0)	1	@VLOOKUP($AF22,$A_ORIGINAL,3)*$CA22
23	@VLOOKUP($AF23,$A_ORIGINAL,2)*$BX23	2*BN23+2*BI23+AP23+BE23+@IF(BL23=1,(AN23*(AG20+AI20)+S*(AS23+AU23))/12,0)	1	@VLOOKUP($AF23,$A_ORIGINAL,3)*$CA23
24	@VLOOKUP($AF24,$A_ORIGINAL,2)*$BX24	2*BN24+2*BI24+AP24+BE24+@IF(BL24=1,(AN24*(AG24+AI24)+S*(AS24+AU24))/12,0)	1	@VLOOKUP($AF24,$A_ORIGINAL,3)*$CA24
25	@VLOOKUP($AF25,$A_ORIGINAL,2)*$BX25	2*BN25+2*BI25+AP25+BE25+@IF(BL25=1,(AN25*(AG25+AI25)+S*(AS25+AU25))/12,0)	1	@VLOOKUP($AF25,$A_ORIGINAL,3)*$CA25
26	@VLOOKUP($AF26,$A_ORIGINAL,2)*$BX26	2*BN26+2*BI26+AP26+BE26+@IF(BL26=1,(AN26*(AG26+AI26)+S*(AS26+AU26))/12,0)	1	@VLOOKUP($AF26,$A_ORIGINAL,3)*$CA26
27	@VLOOKUP($AF27,$A_ORIGINAL,2)*$BX27	2*BN27+2*BI27+AP27+BE27+@IF(BL27=1,(AN27*(AG27+AI27)+S*(AS27+AU27))/12,0)	1	@VLOOKUP($AF27,$A_ORIGINAL,3)*$CA27
28	@VLOOKUP($AF28,$A_ORIGINAL,2)*$BX28	2*BN28+2*BI28+AP28+BE28+@IF(BL28=1,(AN28*(AG28+AI28)+S*(AS28+AU28))/12,0)	1	@VLOOKUP($AF28,$A_ORIGINAL,3)*$CA28
29	@VLOOKUP($AF29,$A_ORIGINAL,2)*$BX29	2*BN29+2*BI29+AP29+BE29+@IF(BL29=1,(AN29*(AG29+AI29)+S*(AS29+AU29))/12,0)	1	@VLOOKUP($AF29,$A_ORIGINAL,3)*$CA29
30	@VLOOKUP($AF30,$A_ORIGINAL,2)*$BX30	2*BN30+2*BI30+AP30+BE30+@IF(BL30=1,(AN30*(AG30+AI30)+S*(AS30+AU30))/12,0)	1	@VLOOKUP($AF30,$A_ORIGINAL,3)*$CA30
31	@VLOOKUP($AF31,$A_ORIGINAL,2)*$BX31	2*BN31+2*BI31+AP31+BE31+@IF(BL31=1,(AN31*(AG31+AI31)+S*(AS31+AU31))/12,0)	1	@VLOOKUP($AF31,$A_ORIGINAL,3)*$CA31
32	@VLOOKUP($AF32,$A_ORIGINAL,2)*$BX32	2*BN32+2*BI32+AP32+BE32+@IF(BL32=1,(AN32*(AG32+AI32)+S*(AS32+AU32))/12,0)	1	@VLOOKUP($AF32,$A_ORIGINAL,3)*$CA32
33	@VLOOKUP($AF33,$A_ORIGINAL,2)*$BX33	2*BN33+2*BI33+AP33+BE33+@IF(BL33=1,(AN33*(AG33+AI33)+S*(AS33+AU33))/12,0)	1	@VLOOKUP($AF33,$A_ORIGINAL,3)*$CA33
34	@VLOOKUP($AF34,$A_ORIGINAL,2)*$BX34	2*BN34+2*BI34+AP34+BE34+@IF(BL34=1,(AN34*(AG34+AI34)+S*(AS34+AU34))/12,0)	1	@VLOOKUP($AF34,$A_ORIGINAL,3)*$CA34
35	@VLOOKUP($AF35,$A_ORIGINAL,2)*$BX35	2*BN35+2*BI35+AP35+BE35+@IF(BL35=1,(AN35*(AG35+AI35)+S*(AS35+AU35))/12,0)	1	@VLOOKUP($AF35,$A_ORIGINAL,3)*$CA35
36	@VLOOKUP($AF36,$A_ORIGINAL,2)*$BX36	2*BN36+2*BI36+AP36+BE36+@IF(BL36=1,(AN36*(AG36+AI36)+S*(AS36+AU36))/12,0)	1	@VLOOKUP($AF36,$A_ORIGINAL,3)*$CA36
37	@VLOOKUP($AF37,$A_ORIGINAL,2)*$BX37	2*BN37+2*BI37+AP37+BE37+@IF(BL37=1,(AN37*(AG37+AI37)+S*(AS37+AU37))/12,0)	1	@VLOOKUP($AF37,$A_ORIGINAL,3)*$CA37
38	@VLOOKUP($AF38,$A_ORIGINAL,2)*$BX38	2*BN38+2*BI38+AP38+BE38+@IF(BL38=1,(AN38*(AG38+AI38)+S*(AS38+AU38))/12,0)	1	@VLOOKUP($AF38,$A_ORIGINAL,3)*$CA38
39	@VLOOKUP($AF39,$A_ORIGINAL,2)*$BX39	2*BN39+2*BI39+AP39+BE39+@IF(BL39=1,(AN39*(AG39+AI39)+S*(AS39+AU39))/12,0)	1	@VLOOKUP($AF39,$A_ORIGINAL,3)*$CA39
40	@VLOOKUP($AF40,$A_ORIGINAL,2)*$BX40	2*BN40+2*BI40+AP40+BE40+@IF(BL40=1,(AN40*(AG40+AI40)+S*(AS40+AU40))/12,0)	1	@VLOOKUP($AF40,$A_ORIGINAL,3)*$CA40
41	@VLOOKUP($AF41,$A_ORIGINAL,2)*$BX41	2*BN41+2*BI41+AP41+BE41+@IF(BL41=1,(AN41*(AG41+AI41)+S*(AS41+AU41))/12,0)	1	@VLOOKUP($AF41,$A_ORIGINAL,3)*$CA41
42	@VLOOKUP($AF42,$A_ORIGINAL,2)*$BX42	2*BN42+2*BI42+AP42+BE42+@IF(BL42=1,(AN42*(AG42+AI42)+S*(AS42+AU42))/12,0)	1	@VLOOKUP($AF42,$A_ORIGINAL,3)*$CA42
43	@VLOOKUP($AF43,$A_ORIGINAL,2)*$BX43	2*BN43+2*BI43+AP43+BE43+@IF(BL43=1,(AN43*(AG43+AI43)+S*(AS43+AU43))/12,0)	1	@VLOOKUP($AF43,$A_ORIGINAL,3)*$CA43
44	@VLOOKUP($AF44,$A_ORIGINAL,2)*$BX44	2*BN44+2*BI44+AP44+BE44+@IF(BL44=1,(AN44*(AG44+AI44)+S*(AS44+AU44))/12,0)	1	@VLOOKUP($AF44,$A_ORIGINAL,3)*$CA44
45	@VLOOKUP($AF45,$A_ORIGINAL,2)*$BX45	2*BN45+2*BI45+AP45+BE45+@IF(BL45=1,(AN45*(AG45+AI45)+S*(AS45+AU45))/12,0)	1	@VLOOKUP($AF45,$A_ORIGINAL,3)*$CA45
46	@VLOOKUP($AF46,$A_ORIGINAL,2)*$BX46	2*BN46+2*BI46+AP46+BE46+@IF(BL46=1,(AN46*(AG46+AI46)+S*(AS46+AU46))/12,0)	1	@VLOOKUP($AF46,$A_ORIGINAL,3)*$CA46
47	@VLOOKUP($AF47,$A_ORIGINAL,2)*$BX47	2*BN47+2*BI47+AP47+BE47+@IF(BL47=1,(AN47*(AG47+AI47)+S*(AS47+AU47))/12,0)	1	@VLOOKUP($AF47,$A_ORIGINAL,3)*$CA47
48	@VLOOKUP($AF48,$A_ORIGINAL,2)*$BX48	2*BN48+2*BI48+AP48+BE48+@IF(BL48=1,(AN48*(AG48+AI48)+S*(AS48+AU48))/12,0)	1	@VLOOKUP($AF48,$A_ORIGINAL,3)*$CA48
49	@VLOOKUP($AF49,$A_ORIGINAL,2)*$BX49	2*BN49+2*BI49+AP49+BE49+@IF(BL49=1,(AN49*(AG49+AI49)+S*(AS49+AU49))/12,0)	1	@VLOOKUP($AF49,$A_ORIGINAL,3)*$CA49
50	@VLOOKUP($AF50,$A_ORIGINAL,2)*$BX50	2*BN50+2*BI50+AP50+BE50+@IF(BL50=1,(AN50*(AG50+AI50)+S*(AS50+AU50))/12,0)	1	@VLOOKUP($AF50,$A_ORIGINAL,3)*$CA50
51	@VLOOKUP($AF51,$A_ORIGINAL,2)*$BX51	2*BN51+2*BI51+AP51+BE51+@IF(BL51=1,(AN51*(AG51+AI51)+S*(AS51+AU51))/12,0)	1	@VLOOKUP($AF51,$A_ORIGINAL,3)*$CA51
52	@VLOOKUP($AF52,$A_ORIGINAL,2)*$BX52	2*BN52+2*BI52+AP52+BE52+@IF(BL52=1,(AN52*(AG52+AI52)+S*(AS52+AU52))/12,0)	1	@VLOOKUP($AF52,$A_ORIGINAL,3)*$CA52
53	@VLOOKUP($AF53,$A_ORIGINAL,2)*$BX53	2*BN53+2*BI53+AP53+BE53+@IF(BL53=1,(AN53*(AG53+AI53)+S*(AS53+AU53))/12,0)	1	@VLOOKUP($AF53,$A_ORIGINAL,3)*$CA53
54	@VLOOKUP($AF54,$A_ORIGINAL,2)*$BX54	2*BN54+2*BI54+AP54+BE54+@IF(BL54=1,(AN54*(AG54+AI54)+S*(AS54+AU54))/12,0)	1	@VLOOKUP($AF54,$A_ORIGINAL,3)*$CA54
55	@VLOOKUP($AF55,$A_ORIGINAL,2)*$BX55	2*BN55+2*BI55+AP55+BE55+@IF(BL55=1,(AN55*(AG55+AI55)+S*(AS55+AU55))/12,0)	1	@VLOOKUP($AF55,$A_ORIGINAL,3)*$CA55
56	@VLOOKUP($AF56,$A_ORIGINAL,2)*$BX56	2*BN56+2*BI56+AP56+BE56+@IF(BL56=1,(AN56*(AG56+AI56)+S*(AS56+AU56))/12,0)	1	@VLOOKUP($AF56,$A_ORIGINAL,3)*$CA56
57	@SUM(BZ56..BZ12)			@SUM(CC56..CC12)

A	CD	CE	CF	CG	CH
1					
2					
3					
4					
5					
6					
7	Edge Prep Vert		Edge Prep Vert	Edge Prep Ovhd	
8	(SStage=2)		(SStage=2)	(SStage=2)	
9					
10					
11					
12	@IF($BL12=2,(($AG12+$AI12)*$AN12+$S*($AS12+$AU12))/12,0)+@IF($DW$4="YES",0,($AP12+$BE12))/10	2	@VLOOKUP($AF12,$A_ORIGINAL,4)*$CD12	@IF($BL12=3,(($AG12+$AI12)*$AN12+$S*($AS12+$AU12))/12,0)	2
13	@IF($BL13=2,(($AG13+$AI13)*$AN13+$S*($AS13+$AU13))/12,0)+@IF($DW$4="YES",0,($AP13+$BE13))/10	2	@VLOOKUP($AF13,$A_ORIGINAL,4)*$CD13	@IF($BL13=3,(($AG13+$AI13)*$AN13+$S*($AS13+$AU13))/12,0)	2
14	@IF($BL14=2,(($AG14+$AI14)*$AN14+$S*($AS14+$AU14))/12,0)+@IF($DW$4="YES",0,($AP14+$BE14))/10	2	@VLOOKUP($AF14,$A_ORIGINAL,4)*$CD14	@IF($BL14=3,(($AG14+$AI14)*$AN14+$S*($AS14+$AU14))/12,0)	2
15	@IF($BL15=2,(($AG15+$AI15)*$AN15+$S*($AS15+$AU15))/12,0)+@IF($DW$4="YES",0,($AP15+$BE15))/10	2	@VLOOKUP($AF15,$A_ORIGINAL,4)*$CD15	@IF($BL15=3,(($AG15+$AI15)*$AN15+$S*($AS15+$AU15))/12,0)	2
16	@IF($BL16=2,(($AG16+$AI16)*$AN16+$S*($AS16+$AU16))/12,0)+@IF($DW$4="YES",0,($AP16+$BE16))/10	2	@VLOOKUP($AF16,$A_ORIGINAL,4)*$CD16	@IF($BL16=3,(($AG16+$AI16)*$AN16+$S*($AS16+$AU16))/12,0)	2
17	@IF($BL17=2,(($AG17+$AI17)*$AN17+$S*($AS17+$AU17))/12,0)+@IF($DW$4="YES",0,($AP17+$BE17))/10	2	@VLOOKUP($AF17,$A_ORIGINAL,4)*$CD17	@IF($BL17=3,(($AG17+$AI17)*$AN17+$S*($AS17+$AU17))/12,0)	2
18	@IF($BL18=2,(($AG18+$AI18)*$AN18+$S*($AS18+$AU18))/12,0)+@IF($DW$4="YES",0,($AP18+$BE18))/10	2	@VLOOKUP($AF18,$A_ORIGINAL,4)*$CD18	@IF($BL18=3,(($AG18+$AI18)*$AN18+$S*($AS18+$AU18))/12,0)	2
19	@IF($BL19=2,(($AG19+$AI19)*$AN19+$S*($AS19+$AU19))/12,0)+@IF($DW$4="YES",0,($AP19+$BE19))/10	2	@VLOOKUP($AF19,$A_ORIGINAL,4)*$CD19	@IF($BL19=3,(($AG19+$AI19)*$AN19+$S*($AS19+$AU19))/12,0)	2
20	@IF($BL20=2,(($AG20+$AI20)*$AN20+$S*($AS20+$AU20))/12,0)+@IF($DW$4="YES",0,($AP20+$BE20))/10	2	@VLOOKUP($AF20,$A_ORIGINAL,4)*$CD20	@IF($BL20=3,(($AG20+$AI20)*$AN20+$S*($AS20+$AU20))/12,0)	2
21	@IF($BL21=2,(($AG21+$AI21)*$AN21+$S*($AS21+$AU21))/12,0)+@IF($DW$4="YES",0,($AP21+$BE21))/10	2	@VLOOKUP($AF21,$A_ORIGINAL,4)*$CD21	@IF($BL21=3,(($AG21+$AI21)*$AN21+$S*($AS21+$AU21))/12,0)	2
22	@IF($BL22=2,(($AG22+$AI22)*$AN22+$S*($AS22+$AU22))/12,0)+@IF($DW$4="YES",0,($AP22+$BE22))/10	2	@VLOOKUP($AF22,$A_ORIGINAL,4)*$CD22	@IF($BL22=3,(($AG22+$AI22)*$AN22+$S*($AS22+$AU22))/12,0)	2
23	@IF($BL23=2,(($AG23+$AI23)*$AN23+$S*($AS23+$AU23))/12,0)+@IF($DW$4="YES",0,($AP23+$BE23))/10	2	@VLOOKUP($AF23,$A_ORIGINAL,4)*$CD23	@IF($BL23=3,(($AG23+$AI23)*$AN23+$S*($AS23+$AU23))/12,0)	2
24	@IF($BL24=2,(($AG24+$AI24)*$AN24+$S*($AS24+$AU24))/12,0)+@IF($DW$4="YES",0,($AP24+$BE24))/10	2	@VLOOKUP($AF24,$A_ORIGINAL,4)*$CD24	@IF($BL24=3,(($AG24+$AI24)*$AN24+$S*($AS24+$AU24))/12,0)	2
25	@IF($BL25=2,(($AG25+$AI25)*$AN25+$S*($AS25+$AU25))/12,0)+@IF($DW$4="YES",0,($AP25+$BE25))/10	2	@VLOOKUP($AF25,$A_ORIGINAL,4)*$CD25	@IF($BL25=3,(($AG25+$AI25)*$AN25+$S*($AS25+$AU25))/12,0)	2
26	@IF($BL26=2,(($AG26+$AI26)*$AN26+$S*($AS26+$AU26))/12,0)+@IF($DW$4="YES",0,($AP26+$BE26))/10	2	@VLOOKUP($AF26,$A_ORIGINAL,4)*$CD26	@IF($BL26=3,(($AG26+$AI26)*$AN26+$S*($AS26+$AU26))/12,0)	2
27	@IF($BL27=2,(($AG27+$AI27)*$AN27+$S*($AS27+$AU27))/12,0)+@IF($DW$4="YES",0,($AP27+$BE27))/10	2	@VLOOKUP($AF27,$A_ORIGINAL,4)*$CD27	@IF($BL27=3,(($AG27+$AI27)*$AN27+$S*($AS27+$AU27))/12,0)	2
28	@IF($BL28=2,(($AG28+$AI28)*$AN28+$S*($AS28+$AU28))/12,0)+@IF($DW$4="YES",0,($AP28+$BE28))/10	2	@VLOOKUP($AF28,$A_ORIGINAL,4)*$CD28	@IF($BL28=3,(($AG28+$AI28)*$AN28+$S*($AS28+$AU28))/12,0)	2
29	@IF($BL29=2,(($AG29+$AI29)*$AN29+$S*($AS29+$AU29))/12,0)+@IF($DW$4="YES",0,($AP29+$BE29))/10	2	@VLOOKUP($AF29,$A_ORIGINAL,4)*$CD29	@IF($BL29=3,(($AG29+$AI29)*$AN29+$S*($AS29+$AU29))/12,0)	2
30	@IF($BL30=2,(($AG30+$AI30)*$AN30+$S*($AS30+$AU30))/12,0)+@IF($DW$4="YES",0,($AP30+$BE30))/10	2	@VLOOKUP($AF30,$A_ORIGINAL,4)*$CD30	@IF($BL30=3,(($AG30+$AI30)*$AN30+$S*($AS30+$AU30))/12,0)	2
31	@IF($BL31=2,(($AG31+$AI31)*$AN31+$S*($AS31+$AU31))/12,0)+@IF($DW$4="YES",0,($AP31+$BE31))/10	2	@VLOOKUP($AF31,$A_ORIGINAL,4)*$CD31	@IF($BL31=3,(($AG31+$AI31)*$AN31+$S*($AS31+$AU31))/12,0)	2
32	@IF($BL32=2,(($AG32+$AI32)*$AN32+$S*($AS32+$AU32))/12,0)+@IF($DW$4="YES",0,($AP32+$BE32))/10	2	@VLOOKUP($AF32,$A_ORIGINAL,4)*$CD32	@IF($BL32=3,(($AG32+$AI32)*$AN32+$S*($AS32+$AU32))/12,0)	2
33	@IF($BL33=2,(($AG33+$AI33)*$AN33+$S*($AS33+$AU33))/12,0)+@IF($DW$4="YES",0,($AP33+$BE33))/10	2	@VLOOKUP($AF33,$A_ORIGINAL,4)*$CD33	@IF($BL33=3,(($AG33+$AI33)*$AN33+$S*($AS33+$AU33))/12,0)	2
34	@IF($BL34=2,(($AG34+$AI34)*$AN34+$S*($AS34+$AU34))/12,0)+@IF($DW$4="YES",0,($AP34+$BE34))/10	2	@VLOOKUP($AF34,$A_ORIGINAL,4)*$CD34	@IF($BL34=3,(($AG34+$AI34)*$AN34+$S*($AS34+$AU34))/12,0)	2
35	@IF($BL35=2,(($AG35+$AI35)*$AN35+$S*($AS35+$AU35))/12,0)+@IF($DW$4="YES",0,($AP35+$BE35))/10	2	@VLOOKUP($AF35,$A_ORIGINAL,4)*$CD35	@IF($BL35=3,(($AG35+$AI35)*$AN35+$S*($AS35+$AU35))/12,0)	2
36	@IF($BL36=2,(($AG36+$AI36)*$AN36+$S*($AS36+$AU36))/12,0)+@IF($DW$4="YES",0,($AP36+$BE36))/10	2	@VLOOKUP($AF36,$A_ORIGINAL,4)*$CD36	@IF($BL36=3,(($AG36+$AI36)*$AN36+$S*($AS36+$AU36))/12,0)	2
37	@IF($BL37=2,(($AG37+$AI37)*$AN37+$S*($AS37+$AU37))/12,0)+@IF($DW$4="YES",0,($AP37+$BE37))/10	2	@VLOOKUP($AF37,$A_ORIGINAL,4)*$CD37	@IF($BL37=3,(($AG37+$AI37)*$AN37+$S*($AS37+$AU37))/12,0)	2
38	@IF($BL38=2,(($AG38+$AI38)*$AN38+$S*($AS38+$AU38))/12,0)+@IF($DW$4="YES",0,($AP38+$BE38))/10	2	@VLOOKUP($AF38,$A_ORIGINAL,4)*$CD38	@IF($BL38=3,(($AG38+$AI38)*$AN38+$S*($AS38+$AU38))/12,0)	2
39	@IF($BL39=2,(($AG39+$AI39)*$AN39+$S*($AS39+$AU39))/12,0)+@IF($DW$4="YES",0,($AP39+$BE39))/10	2	@VLOOKUP($AF39,$A_ORIGINAL,4)*$CD39	@IF($BL39=3,(($AG39+$AI39)*$AN39+$S*($AS39+$AU39))/12,0)	2
40	@IF($BL40=2,(($AG40+$AI40)*$AN40+$S*($AS40+$AU40))/12,0)+@IF($DW$4="YES",0,($AP40+$BE40))/10	2	@VLOOKUP($AF40,$A_ORIGINAL,4)*$CD40	@IF($BL40=3,(($AG40+$AI40)*$AN40+$S*($AS40+$AU40))/12,0)	2
41	@IF($BL41=2,(($AG41+$AI41)*$AN41+$S*($AS41+$AU41))/12,0)+@IF($DW$4="YES",0,($AP41+$BE41))/10	2	@VLOOKUP($AF41,$A_ORIGINAL,4)*$CD41	@IF($BL41=3,(($AG41+$AI41)*$AN41+$S*($AS41+$AU41))/12,0)	2
42	@IF($BL42=2,(($AG42+$AI42)*$AN42+$S*($AS42+$AU42))/12,0)+@IF($DW$4="YES",0,($AP42+$BE42))/10	2	@VLOOKUP($AF42,$A_ORIGINAL,4)*$CD42	@IF($BL42=3,(($AG42+$AI42)*$AN42+$S*($AS42+$AU42))/12,0)	2
43	@IF($BL43=2,(($AG43+$AI43)*$AN43+$S*($AS43+$AU43))/12,0)+@IF($DW$4="YES",0,($AP43+$BE43))/10	2	@VLOOKUP($AF43,$A_ORIGINAL,4)*$CD43	@IF($BL43=3,(($AG43+$AI43)*$AN43+$S*($AS43+$AU43))/12,0)	2
44	@IF($BL44=2,(($AG44+$AI44)*$AN44+$S*($AS44+$AU44))/12,0)+@IF($DW$4="YES",0,($AP44+$BE44))/10	2	@VLOOKUP($AF44,$A_ORIGINAL,4)*$CD44	@IF($BL44=3,(($AG44+$AI44)*$AN44+$S*($AS44+$AU44))/12,0)	2
45	@IF($BL45=2,(($AG45+$AI45)*$AN45+$S*($AS45+$AU45))/12,0)+@IF($DW$4="YES",0,($AP45+$BE45))/10	2	@VLOOKUP($AF45,$A_ORIGINAL,4)*$CD45	@IF($BL45=3,(($AG45+$AI45)*$AN45+$S*($AS45+$AU45))/12,0)	2
46	@IF($BL46=2,(($AG46+$AI46)*$AN46+$S*($AS46+$AU46))/12,0)+@IF($DW$4="YES",0,($AP46+$BE46))/10	2	@VLOOKUP($AF46,$A_ORIGINAL,4)*$CD46	@IF($BL46=3,(($AG46+$AI46)*$AN46+$S*($AS46+$AU46))/12,0)	2
47	@IF($BL47=2,(($AG47+$AI47)*$AN47+$S*($AS47+$AU47))/12,0)+@IF($DW$4="YES",0,($AP47+$BE47))/10	2	@VLOOKUP($AF47,$A_ORIGINAL,4)*$CD47	@IF($BL47=3,(($AG47+$AI47)*$AN47+$S*($AS47+$AU47))/12,0)	2
48	@IF($BL48=2,(($AG48+$AI48)*$AN48+$S*($AS48+$AU48))/12,0)+@IF($DW$4="YES",0,($AP48+$BE48))/10	2	@VLOOKUP($AF48,$A_ORIGINAL,4)*$CD48	@IF($BL48=3,(($AG48+$AI48)*$AN48+$S*($AS48+$AU48))/12,0)	2
49	@IF($BL49=2,(($AG49+$AI49)*$AN49+$S*($AS49+$AU49))/12,0)+@IF($DW$4="YES",0,($AP49+$BE49))/10	2	@VLOOKUP($AF49,$A_ORIGINAL,4)*$CD49	@IF($BL49=3,(($AG49+$AI49)*$AN49+$S*($AS49+$AU49))/12,0)	2
50	@IF($BL50=2,(($AG50+$AI50)*$AN50+$S*($AS50+$AU50))/12,0)+@IF($DW$4="YES",0,($AP50+$BE50))/10	2	@VLOOKUP($AF50,$A_ORIGINAL,4)*$CD50	@IF($BL50=3,(($AG50+$AI50)*$AN50+$S*($AS50+$AU50))/12,0)	2
51	@IF($BL51=2,(($AG51+$AI51)*$AN51+$S*($AS51+$AU51))/12,0)+@IF($DW$4="YES",0,($AP51+$BE51))/10	2	@VLOOKUP($AF51,$A_ORIGINAL,4)*$CD51	@IF($BL51=3,(($AG51+$AI51)*$AN51+$S*($AS51+$AU51))/12,0)	2
52	@IF($BL52=2,(($AG52+$AI52)*$AN52+$S*($AS52+$AU52))/12,0)+@IF($DW$4="YES",0,($AP52+$BE52))/10	2	@VLOOKUP($AF52,$A_ORIGINAL,4)*$CD52	@IF($BL52=3,(($AG52+$AI52)*$AN52+$S*($AS52+$AU52))/12,0)	2
53	@IF($BL53=2,(($AG53+$AI53)*$AN53+$S*($AS53+$AU53))/12,0)+@IF($DW$4="YES",0,($AP53+$BE53))/10	2	@VLOOKUP($AF53,$A_ORIGINAL,4)*$CD53	@IF($BL53=3,(($AG53+$AI53)*$AN53+$S*($AS53+$AU53))/12,0)	2
54	@IF($BL54=2,(($AG54+$AI54)*$AN54+$S*($AS54+$AU54))/12,0)+@IF($DW$4="YES",0,($AP54+$BE54))/10	2	@VLOOKUP($AF54,$A_ORIGINAL,4)*$CD54	@IF($BL54=3,(($AG54+$AI54)*$AN54+$S*($AS54+$AU54))/12,0)	2
55	@IF($BL55=2,(($AG55+$AI55)*$AN55+$S*($AS55+$AU55))/12,0)+@IF($DW$4="YES",0,($AP55+$BE55))/10	2	@VLOOKUP($AF55,$A_ORIGINAL,4)*$CD55	@IF($BL55=3,(($AG55+$AI55)*$AN55+$S*($AS55+$AU55))/12,0)	2
56	@IF($BL56=2,(($AG56+$AI56)*$AN56+$S*($AS56+$AU56))/12,0)+@IF($DW$4="YES",0,($AP56+$BE56))/10	2	@VLOOKUP($AF56,$A_ORIGINAL,4)*$CD56	@IF($BL56=3,(($AG56+$AI56)*$AN56+$S*($AS56+$AU56))/12,0)	2
57			@SUM(CF56..CF12)		

A	CI	CJ
1		
2		
3		
4		
5		
6		
7	Edge Prep Ovhd	Shape - Roll
8	(SStage=2)	(SStage=1)
9		# of Shapes
10		
11		
12	@VLOOKUP($AF12,$A_ORIGINAL,5)*$CG12	@IF($C89="*R",$AD12,0)+@IF($S89="*R",$S,0)+@IF($C89="*R"#OR#$S97="*R",1,0)
13	@VLOOKUP($AF13,$A_ORIGINAL,5)*$CG13	@IF($C90="*R",$AD13,0)+@IF($S90="*R",$S,0)+@IF($C90="*R"#OR#$S98="*R",1,0)
14	@VLOOKUP($AF14,$A_ORIGINAL,5)*$CG14	@IF($C91="*R",$AD14,0)+@IF($S91="*R",$S,0)+@IF($C91="*R"#OR#$S99="*R",1,0)
15	@VLOOKUP($AF15,$A_ORIGINAL,5)*$CG15	@IF($C92="*R",$AD15,0)+@IF($S92="*R",$S,0)+@IF($C92="*R"#OR#$S100="*R",1,0)
16	@VLOOKUP($AF16,$A_ORIGINAL,5)*$CG16	@IF($C93="*R",$AD16,0)+@IF($S93="*R",$S,0)+@IF($C93="*R"#OR#$S101="*R",1,0)
17	@VLOOKUP($AF17,$A_ORIGINAL,5)*$CG17	@IF($C94="*R",$AD17,0)+@IF($S94="*R",$S,0)+@IF($C94="*R"#OR#$S102="*R",1,0)
18	@VLOOKUP($AF18,$A_ORIGINAL,5)*$CG18	@IF($C95="*R",$AD18,0)+@IF($S95="*R",$S,0)+@IF($C95="*R"#OR#$S103="*R",1,0)
19	@VLOOKUP($AF19,$A_ORIGINAL,5)*$CG19	@IF($C96="*R",$AD19,0)+@IF($S96="*R",$S,0)+@IF($C96="*R"#OR#$S104="*R",1,0)
20	@VLOOKUP($AF20,$A_ORIGINAL,5)*$CG20	@IF($C97="*R",$AD20,0)+@IF($S97="*R",$S,0)+@IF($C97="*R"#OR#$S105="*R",1,0)
21	@VLOOKUP($AF21,$A_ORIGINAL,5)*$CG21	@IF($C98="*R",$AD21,0)+@IF($S98="*R",$S,0)+@IF($C98="*R"#OR#$S106="*R",1,0)
22	@VLOOKUP($AF22,$A_ORIGINAL,5)*$CG22	@IF($C99="*R",$AD22,0)+@IF($S99="*R",$S,0)+@IF($C99="*R"#OR#$S107="*R",1,0)
23	@VLOOKUP($AF23,$A_ORIGINAL,5)*$CG23	@IF($C100="*R",$AD23,0)+@IF($S100="*R",$S,0)+@IF($C100="*R"#OR#$S108="*R",1,0)
24	@VLOOKUP($AF24,$A_ORIGINAL,5)*$CG24	@IF($C101="*R",$AD24,0)+@IF($S101="*R",$S,0)+@IF($C101="*R"#OR#$S109="*R",1,0)
25	@VLOOKUP($AF25,$A_ORIGINAL,5)*$CG25	@IF($C102="*R",$AD25,0)+@IF($S102="*R",$S,0)+@IF($C102="*R"#OR#$S110="*R",1,0)
26	@VLOOKUP($AF26,$A_ORIGINAL,5)*$CG26	@IF($C103="*R",$AD26,0)+@IF($S103="*R",$S,0)+@IF($C103="*R"#OR#$S111="*R",1,0)
27	@VLOOKUP($AF27,$A_ORIGINAL,5)*$CG27	@IF($C104="*R",$AD27,0)+@IF($S104="*R",$S,0)+@IF($C104="*R"#OR#$S112="*R",1,0)
28	@VLOOKUP($AF28,$A_ORIGINAL,5)*$CG28	@IF($C105="*R",$AD28,0)+@IF($S105="*R",$S,0)+@IF($C105="*R"#OR#$S113="*R",1,0)
29	@VLOOKUP($AF29,$A_ORIGINAL,5)*$CG29	@IF($C106="*R",$AD29,0)+@IF($S106="*R",$S,0)+@IF($C106="*R"#OR#$S114="*R",1,0)
30	@VLOOKUP($AF30,$A_ORIGINAL,5)*$CG30	@IF($C107="*R",$AD30,0)+@IF($S107="*R",$S,0)+@IF($C107="*R"#OR#$S115="*R",1,0)
31	@VLOOKUP($AF31,$A_ORIGINAL,5)*$CG31	@IF($C108="*R",$AD31,0)+@IF($S108="*R",$S,0)+@IF($C108="*R"#OR#$S116="*R",1,0)
32	@VLOOKUP($AF32,$A_ORIGINAL,5)*$CG32	@IF($C109="*R",$AD32,0)+@IF($S109="*R",$S,0)+@IF($C109="*R"#OR#$S117="*R",1,0)
33	@VLOOKUP($AF33,$A_ORIGINAL,5)*$CG33	@IF($C110="*R",$AD33,0)+@IF($S110="*R",$S,0)+@IF($C110="*R"#OR#$S118="*R",1,0)
34	@VLOOKUP($AF34,$A_ORIGINAL,5)*$CG34	@IF($C111="*R",$AD34,0)+@IF($S111="*R",$S,0)+@IF($C111="*R"#OR#$S119="*R",1,0)
35	@VLOOKUP($AF35,$A_ORIGINAL,5)*$CG35	@IF($C112="*R",$AD35,0)+@IF($S112="*R",$S,0)+@IF($C112="*R"#OR#$S120="*R",1,0)
36	@VLOOKUP($AF36,$A_ORIGINAL,5)*$CG36	@IF($C113="*R",$AD36,0)+@IF($S113="*R",$S,0)+@IF($C113="*R"#OR#$S121="*R",1,0)
37	@VLOOKUP($AF37,$A_ORIGINAL,5)*$CG37	@IF($C114="*R",$AD37,0)+@IF($S114="*R",$S,0)+@IF($C114="*R"#OR#$S122="*R",1,0)
38	@VLOOKUP($AF38,$A_ORIGINAL,5)*$CG38	@IF($C115="*R",$AD38,0)+@IF($S115="*R",$S,0)+@IF($C115="*R"#OR#$S123="*R",1,0)
39	@VLOOKUP($AF39,$A_ORIGINAL,5)*$CG39	@IF($C116="*R",$AD39,0)+@IF($S116="*R",$S,0)+@IF($C116="*R"#OR#$S124="*R",1,0)
40	@VLOOKUP($AF40,$A_ORIGINAL,5)*$CG40	n/a
41	@VLOOKUP($AF41,$A_ORIGINAL,5)*$CG41	n/a
42	@VLOOKUP($AF42,$A_ORIGINAL,5)*$CG42	n/a
43	@VLOOKUP($AF43,$A_ORIGINAL,5)*$CG43	n/a
44	@VLOOKUP($AF44,$A_ORIGINAL,5)*$CG44	@IF($S89="*R",$S,0)
45	@VLOOKUP($AF45,$A_ORIGINAL,5)*$CG45	@IF($S90="*R",$S,0)
46	@VLOOKUP($AF46,$A_ORIGINAL,5)*$CG46	@IF($S91="*R",$S,0)
47	@VLOOKUP($AF47,$A_ORIGINAL,5)*$CG47	@IF($S92="*R",$S,0)
48	@VLOOKUP($AF48,$A_ORIGINAL,5)*$CG48	@IF($S93="*R",$S,0)
49	@VLOOKUP($AF49,$A_ORIGINAL,5)*$CG49	@IF($S94="*R",$S,0)
50	@VLOOKUP($AF50,$A_ORIGINAL,5)*$CG50	@IF($S95="*R",$S,0)
51	@VLOOKUP($AF51,$A_ORIGINAL,5)*$CG51	@IF($S96="*R",$S,0)
52	@VLOOKUP($AF52,$A_ORIGINAL,5)*$CG52	@IF($S97="*R",$S,0)
53	@VLOOKUP($AF53,$A_ORIGINAL,5)*$CG53	@IF($S98="*R",$S,0)
54	@VLOOKUP($AF54,$A_ORIGINAL,5)*$CG54	@IF($S99="*R",$S,0)
55	@VLOOKUP($AF55,$A_ORIGINAL,5)*$CG55	@IF($S100="*R",$S,0)
56	@VLOOKUP($AF56,$A_ORIGINAL,5)*$CG56	@IF($S101="*R",$S,0)
57	@SUM(CI56..CI12)	

A	CK	CL	CM
1			
2			
3			
4			
5			
6			
7	Shape - Roll	Shape - Line Ht	Shape - Line Ht
8	(SStage=1)	(SStage=1)	(SStage=1)
9			
10			
11			
12	@IF($C89="*R",@VLOOKUP($F89,$B_ORIGINAL,7)*$AD12,0)+@IF($AE97="*R",@VLOOKUP($AH97,$B_ORIGINAL,7)*$S,0)+@IF($C89="*R"#OR#$AE97="*R",@VLOOKUP($AF12,$B_ORIGINAL,7)*$S,0)	@IF($BM12=2,$BJ12+$S+$AD12,0)	+CL12
13	@IF($C90="*R",@VLOOKUP($F90,$B_ORIGINAL,7)*$AD13,0)+@IF($AE98="*R",@VLOOKUP($AH98,$B_ORIGINAL,7)*$S,0)+@IF($C90="*R"#OR#$AE98="*R",@VLOOKUP($AF13,$B_ORIGINAL,7)*$S,0)	@IF($BM13=2,$BJ13+$S+$AD13,0)	+CL13
14	@IF($C91="*R",@VLOOKUP($F91,$B_ORIGINAL,7)*$AD14,0)+@IF($AE99="*R",@VLOOKUP($AH99,$B_ORIGINAL,7)*$S,0)+@IF($C91="*R"#OR#$AE99="*R",@VLOOKUP($AF14,$B_ORIGINAL,7)*$S,0)	@IF($BM14=2,$BJ14+$S+$AD14,0)	+CL14
15	@IF($C92="*R",@VLOOKUP($F92,$B_ORIGINAL,7)*$AD15,0)+@IF($AE100="*R",@VLOOKUP($AH100,$B_ORIGINAL,7)*$S,0)+@IF($C92="*R"#OR#$AE100="*R",@VLOOKUP($AF15,$B_ORIGINAL,7)*$S,0)	@IF($BM15=2,$BJ15+$S+$AD15,0)	+CL15
16	@IF($C93="*R",@VLOOKUP($F93,$B_ORIGINAL,7)*$AD16,0)+@IF($AE101="*R",@VLOOKUP($AH101,$B_ORIGINAL,7)*$S,0)+@IF($C93="*R"#OR#$AE101="*R",@VLOOKUP($AF16,$B_ORIGINAL,7)*$S,0)	@IF($BM16=2,$BJ16+$S+$AD16,0)	+CL16
17	@IF($C94="*R",@VLOOKUP($F94,$B_ORIGINAL,7)*$AD17,0)+@IF($AE102="*R",@VLOOKUP($AH102,$B_ORIGINAL,7)*$S,0)+@IF($C94="*R"#OR#$AE102="*R",@VLOOKUP($AF17,$B_ORIGINAL,7)*$S,0)	@IF($BM17=2,$BJ17+$S+$AD17,0)	+CL17
18	@IF($C95="*R",@VLOOKUP($F95,$B_ORIGINAL,7)*$AD18,0)+@IF($AE103="*R",@VLOOKUP($AH103,$B_ORIGINAL,7)*$S,0)+@IF($C95="*R"#OR#$AE103="*R",@VLOOKUP($AF18,$B_ORIGINAL,7)*$S,0)	@IF($BM18=2,$BJ18+$S+$AD18,0)	+CL18
19	@IF($C96="*R",@VLOOKUP($F96,$B_ORIGINAL,7)*$AD19,0)+@IF($AE104="*R",@VLOOKUP($AH104,$B_ORIGINAL,7)*$S,0)+@IF($C96="*R"#OR#$AE104="*R",@VLOOKUP($AF19,$B_ORIGINAL,7)*$S,0)	@IF($BM19=2,$BJ19+$S+$AD19,0)	+CL19
20	@IF($C97="*R",@VLOOKUP($F97,$B_ORIGINAL,7)*$AD20,0)+@IF($AE105="*R",@VLOOKUP($AH105,$B_ORIGINAL,7)*$S,0)+@IF($C97="*R"#OR#$AE105="*R",@VLOOKUP($AF20,$B_ORIGINAL,7)*$S,0)	@IF($BM20=2,$BJ20+$S+$AD20,0)	+CL20
21	@IF($C98="*R",@VLOOKUP($F98,$B_ORIGINAL,7)*$AD21,0)+@IF($AE106="*R",@VLOOKUP($AH106,$B_ORIGINAL,7)*$S,0)+@IF($C98="*R"#OR#$AE106="*R",@VLOOKUP($AF21,$B_ORIGINAL,7)*$S,0)	@IF($BM21=2,$BJ21+$S+$AD21,0)	+CL21
22	@IF($C99="*R",@VLOOKUP($F99,$B_ORIGINAL,7)*$AD22,0)+@IF($AE107="*R",@VLOOKUP($AH107,$B_ORIGINAL,7)*$S,0)+@IF($C99="*R"#OR#$AE107="*R",@VLOOKUP($AF22,$B_ORIGINAL,7)*$S,0)	@IF($BM22=2,$BJ22+$S+$AD22,0)	+CL22
23	@IF($C100="*R",@VLOOKUP($F100,$B_ORIGINAL,7)*$AD23,0)+@IF($AE108="*R",@VLOOKUP($AH108,$B_ORIGINAL,7)*$S,0)+@IF($C100="*R"#OR#$AE108="*R",@VLOOKUP($AF23,$B_ORIGINAL,7)*$S,	@IF($BM23=2,$BJ23+$S+$AD23,0)	+CL23
24	@IF($C101="*R",@VLOOKUP($F101,$B_ORIGINAL,7)*$AD24,0)+@IF($AE109="*R",@VLOOKUP($AH109,$B_ORIGINAL,7)*$S,0)+@IF($C101="*R"#OR#$AE109="*R",@VLOOKUP($AF24,$B_ORIGINAL,7)*$S,	@IF($BM24=2,$BJ24+$S+$AD24,0)	+CL24
25	@IF($C102="*R",@VLOOKUP($F102,$B_ORIGINAL,7)*$AD25,0)+@IF($C102="*R",@VLOOKUP($AF25,$B_ORIGINAL,7)*$S,0)	@IF($BM25=2,$BJ25+$S+$AD25,0)	+CL25
26	@IF($C103="*R",@VLOOKUP($F103,$B_ORIGINAL,7)*$AD26,0)+@IF($C103="*R",@VLOOKUP($AF26,$B_ORIGINAL,7)*$S,0)	@IF($BM26=2,$BJ26+$S+$AD26,0)	+CL26
27	@IF($C104="*R",@VLOOKUP($F104,$B_ORIGINAL,7)*$AD27,0)+@IF($C104="*R",@VLOOKUP($AF27,$B_ORIGINAL,7)*$S,0)	@IF($BM27=2,$BJ27+$S+$AD27,0)	+CL27
28	@IF($C105="*R",@VLOOKUP($F105,$B_ORIGINAL,7)*$AD28,0)+@IF($C105="*R",@VLOOKUP($AF28,$B_ORIGINAL,7)*$S,0)	@IF($BM28=2,$BJ28+$S+$AD28,0)	+CL28
29	@IF($C106="*R",@VLOOKUP($F106,$B_ORIGINAL,7)*$AD29,0)+@IF($C106="*R",@VLOOKUP($AF29,$B_ORIGINAL,7)*$S,0)	@IF($BM29=2,$BJ29+$S+$AD29,0)	+CL29
30	@IF($C107="*R",@VLOOKUP($F107,$B_ORIGINAL,7)*$AD30,0)+@IF($AE115="*R",@VLOOKUP($AH115,$B_ORIGINAL,7)*$S,0)+@IF($C107="*R"#OR#$AE115="*R",@VLOOKUP($AF30,$B_ORIGINAL,7)*$S,	@IF($BM30=2,$BJ30+$S+$AD30,0)	+CL30
31	@IF($C108="*R",@VLOOKUP($F108,$B_ORIGINAL,7)*$AD31,0)+@IF($AE116="*R",@VLOOKUP($AH116,$B_ORIGINAL,7)*$S,0)+@IF($C108="*R"#OR#$AE116="*R",@VLOOKUP($AF31,$B_ORIGINAL,7)*$S,	@IF($BM31=2,$BJ31+$S+$AD31,0)	+CL31
32	@IF($C109="*R",@VLOOKUP($F109,$B_ORIGINAL,7)*$AD32,0)+@IF($AE117="*R",@VLOOKUP($AH117,$B_ORIGINAL,7)*$S,0)+@IF($C109="*R"#OR#$AE117="*R",@VLOOKUP($AF32,$B_ORIGINAL,7)*$S,	@IF($BM32=2,$BJ32+$S+$AD32,0)	+CL32
33	@IF($C110="*R",@VLOOKUP($F110,$B_ORIGINAL,7)*$AD33,0)+@IF($AE118="*R",@VLOOKUP($AH118,$B_ORIGINAL,7)*$S,0)+@IF($C110="*R"#OR#$AE118="*R",@VLOOKUP($AF33,$B_ORIGINAL,7)*$S,	@IF($BM33=2,$BJ33+$S+$AD33,0)	+CL33
34	@IF($C111="*R",@VLOOKUP($F111,$B_ORIGINAL,7)*$AD34,0)+@IF($AE119="*R",@VLOOKUP($AH119,$B_ORIGINAL,7)*$S,0)+@IF($C111="*R"#OR#$AE119="*R",@VLOOKUP($AF34,$B_ORIGINAL,7)*$S,	@IF($BM34=2,$BJ34+$S+$AD34,0)	+CL34
35	@IF($C112="*R",@VLOOKUP($F112,$B_ORIGINAL,7)*$AD35,0)+@IF($AE120="*R",@VLOOKUP($AH120,$B_ORIGINAL,7)*$S,0)+@IF($C112="*R"#OR#$AE120="*R",@VLOOKUP($AF35,$B_ORIGINAL,7)*$S,	@IF($BM35=2,$BJ35+$S+$AD35,0)	+CL35
36	@IF($C113="*R",@VLOOKUP($F113,$B_ORIGINAL,7)*$AD36,0)+@IF($AE121="*R",@VLOOKUP($AH121,$B_ORIGINAL,7)*$S,0)+@IF($C113="*R"#OR#$AE121="*R",@VLOOKUP($AF36,$B_ORIGINAL,7)*$S,	@IF($BM36=2,$BJ36+$S+$AD36,0)	+CL36
37	@IF($C114="*R",@VLOOKUP($F114,$B_ORIGINAL,7)*$AD37,0)+@IF($AE122="*R",@VLOOKUP($AH122,$B_ORIGINAL,7)*$S,0)+@IF($C114="*R"#OR#$AE122="*R",@VLOOKUP($AF37,$B_ORIGINAL,7)*$S,	@IF($BM37=2,$BJ37+$S+$AD37,0)	+CL37
38	@IF($C115="*R",@VLOOKUP($F115,$B_ORIGINAL,7)*$AD38,0)+@IF($AE123="*R",@VLOOKUP($AH123,$B_ORIGINAL,7)*$S,0)+@IF($C115="*R"#OR#$AE123="*R",@VLOOKUP($AF38,$B_ORIGINAL,7)*$S,	@IF($BM38=2,$BJ38+$S+$AD38,0)	+CL38
39	@IF($C116="*R",@VLOOKUP($F116,$B_ORIGINAL,7)*$AD39,0)+@IF($AF124="*R",@VLOOKUP($Y137,$B_ORIGINAL,7)*$S,0)+@IF($C116="*R"#OR#$AF124="*R",@VLOOKUP($AF39,$B_ORIGINAL,7)*$S,0)	@IF($BM39=2,$BJ39+$S+$AD39,0)	+CL39
40	n/a	@IF($BM40=2,$BJ40+$S+$AD40,0)	+CL40
41	n/a	@IF($BM41=2,$BJ41+$S+$AD41,0)	+CL41
42	n/a	@IF($BM42=2,$BJ42+$S+$AD42,0)	+CL42
43	n/a	@IF($BM43=2,$BJ43+$S+$AD43,0)	+CL43
44	@IF($S89="*R",@VLOOKUP($V89,$B_ORIGINAL,7)*$S,0)	@IF($BM44=2,$BJ44+$S+$AD44,0)	+CL44
45	@IF($S90="*R",@VLOOKUP($V90,$B_ORIGINAL,7)*$S,0)	@IF($BM45=2,$BJ45+$S+$AD45,0)	+CL45
46	@IF($S91="*R",@VLOOKUP($V91,$B_ORIGINAL,7)*$S,0)	@IF($BM46=2,$BJ46+$S+$AD46,0)	+CL46
47	@IF($S92="*R",@VLOOKUP($V92,$B_ORIGINAL,7)*$S,0)	@IF($BM47=2,$BJ47+$S+$AD47,0)	+CL47
48	@IF($S93="*R",@VLOOKUP($V93,$B_ORIGINAL,7)*$S,0)	@IF($BM48=2,$BJ48+$S+$AD48,0)	+CL48
49	@IF($S94="*R",@VLOOKUP($V94,$B_ORIGINAL,7)*$S,0)	@IF($BM49=2,$BJ49+$S+$AD49,0)	+CL49
50	@IF($S95="*R",@VLOOKUP($V95,$B_ORIGINAL,7)*$S,0)	@IF($BM50=2,$BJ50+$S+$AD50,0)	+CL50
51	@IF($S96="*R",@VLOOKUP($V96,$B_ORIGINAL,7)*$S,0)	@IF($BM51=2,$BJ51+$S+$AD51,0)	+CL51
52	@IF($S97="*R",@VLOOKUP($V97,$B_ORIGINAL,7)*$S,0)	@IF($BM52=2,$BJ52+$S+$AD52,0)	+CL52
53	@IF($S98="*R",@VLOOKUP($V98,$B_ORIGINAL,7)*$S,0)	@IF($BM53=2,$BJ53+$S+$AD53,0)	+CL53
54	@IF($S99="*R",@VLOOKUP($V99,$B_ORIGINAL,7)*$S,0)	@IF($BM54=2,$BJ54+$S+$AD54,0)	+CL54
55	@IF($S100="*R",@VLOOKUP($V100,$B_ORIGINAL,7)*$S,0)	@IF($BM55=2,$BJ55+$S+$AD55,0)	+CL55
56	@IF($S101="*R",@VLOOKUP($V101,$B_ORIGINAL,7)*$S,0)	@IF($BM56=2,$BJ56+$S+$AD56,0)	+CL56
57	@SUM(CK56..CK12)		@SUM(CM56

A	CN	CO	CP	CQ	CR	CS
1						
2						
3						
4						
5						
6						
7	Fit-Up &		Fit-Up &			
8	Assembly		Assembly	Distortion	Distortion	Distortion
9						
10						
11						
12	(($S-1)*$BI12+$AD12*($AO12+$AI12)+$S*($AS12+$AU12)/2)/12+($A*$S+$AP12+$BE12)	2	@VLOOKUP($AF12,$A_ORIGINAL,6)*CN12	@IF($BO12="n/a",0,$BO12)	@EXP((-15)*($AF12)^2)	@VLOOKUP($AF12,$LOOKUP_HTS_C,3)*$AF12
13	(($S-1)*$BI13+$AD13*($AO13+$AI13)+$S*($AS13+$AU13)/2)/12+($A*$S+$AP13+$BE13)	2	@VLOOKUP($AF13,$A_ORIGINAL,6)*CN13	@IF($BO13="n/a",0,$BO13)	@EXP((-15)*($AF13)^2)	@VLOOKUP($AF13,$LOOKUP_HTS_C,3)*$AF13
14	(($S-1)*$BI14+$AD14*($AO14+$AI14)+$S*($AS14+$AU14)/2)/12+($A*$S+$AP14+$BE14)	2	@VLOOKUP($AF14,$A_ORIGINAL,6)*CN14	@IF($BO14="n/a",0,$BO14)	@EXP((-15)*($AF14)^2)	@VLOOKUP($AF14,$LOOKUP_HTS_C,3)*$AF14
15	(($S-1)*$BI15+$AD15*($AO15+$AI15)+$S*($AS15+$AU15)/2)/12+($A*$S+$AP15+$BE15)	2	@VLOOKUP($AF15,$A_ORIGINAL,6)*CN15	@IF($BO15="n/a",0,$BO15)	@EXP((-15)*($AF15)^2)	@VLOOKUP($AF15,$LOOKUP_HTS_C,3)*$AF15
16	(($S-1)*$BI16+$AD16*($AG16+$AI16)+$S*($AS16+$AU16)/2)/12+($A*$S+$AP16+$BE16)	2	@VLOOKUP($AF16,$A_ORIGINAL,6)*CN16	@IF($BO16="n/a",0,$BO16)	@EXP((-15)*($AF16)^2)	@VLOOKUP($AF16,$LOOKUP_HTS_C,3)*$AF16
17	(($S-1)*$BI17+$AD17*($AO17+$AI17)+$S*($AS17+$AU17)/2)/12+($A*$S+$AP17+$BE17)	2	@VLOOKUP($AF17,$A_ORIGINAL,6)*CN17	@IF($BO17="n/a",0,$BO17)	@EXP((-15)*($AF17)^2)	@VLOOKUP($AF17,$LOOKUP_HTS_C,3)*$AF17
18	(($S-1)*$BI18+$AD18*($AO18+$AI18)+$S*($AS18+$AU18)/2)/12+($A*$S+$AP18+$BE18)	2	@VLOOKUP($AF18,$A_ORIGINAL,6)*CN18	@IF($BO18="n/a",0,$BO18)	@EXP((-15)*($AF18)^2)	@VLOOKUP($AF18,$LOOKUP_HTS_C,3)*$AF18
19	(($S-1)*$BI19+$AD19*($AG19+$AI19)+$S*($AS19+$AU19)/2)/12+($A*$S+$AP19+$BE19)	2	@VLOOKUP($AF19,$A_ORIGINAL,6)*CN19	@IF($BO19="n/a",0,$BO19)	@EXP((-15)*($AF19)^2)	@VLOOKUP($AF19,$LOOKUP_HTS_C,3)*$AF19
20	(($S-1)*$BI20+$AD20*($AG20+$AI20)+$S*($AS20+$AU20)/2)/12+($A*$S+$AP20+$BE20)	2	@VLOOKUP($AF20,$A_ORIGINAL,6)*CN20	@IF($BO20="n/a",0,$BO20)	@EXP((-15)*($AF20)^2)	@VLOOKUP($AF20,$LOOKUP_HTS_C,3)*$AF20
21	(($S-1)*$BI21+$AD21*($AO21+$AI21)+$S*($AS21+$AU21)/2)/12+($A*$S+$AP21+$BE21)	2	@VLOOKUP($AF21,$A_ORIGINAL,6)*CN21	@IF($BO21="n/a",0,$BO21)	@EXP((-15)*($AF21)^2)	@VLOOKUP($AF21,$LOOKUP_HTS_C,3)*$AF21
22	(($S-1)*$BI22+$AD22*($AO22+$AI22)+$S*($AS22+$AU22)/2)/12+($A*$S+$AP22+$BE22)	2	@VLOOKUP($AF22,$A_ORIGINAL,6)*CN22	@IF($BO22="n/a",0,$BO22)	@EXP((-15)*($AF22)^2)	@VLOOKUP($AF22,$LOOKUP_HTS_C,3)*$AF22
23	(($S-1)*$BI23+$AD23*($AO23+$AI23)+$S*($AS23+$AU23)/2)/12+($A*$S+$AP23+$BE23)		@VLOOKUP($AF23,$A_ORIGINAL,6)*CN23	@IF($BO23="n/a",0,$BO23)	@EXP((-15)*($AF23)^2)	@VLOOKUP($AF23,$LOOKUP_HTS_C,3)*$AF23
24	(($S-1)*$BI24+$AD24*($AO24+$AI24)+$S*($AS24+$AU24)/2)/12+($A*$S+$AP24+$BE24)		@VLOOKUP($AF24,$A_ORIGINAL,6)*CN24	@IF($BO24="n/a",0,$BO24)	@EXP((-15)*($AF24)^2)	@VLOOKUP($AF24,$LOOKUP_HTS_C,3)*$AF24
25	(($S-1)*$BI25+$AD25*($AO25+$AI25)+$S*($AS25+$AU25)/2)/12+($A*$S+$AP25+$BE25)	2	@VLOOKUP($AF25,$A_ORIGINAL,6)*CN25	@IF($BO25="n/a",0,$BO25)	@EXP((-15)*($AF25)^2)	@VLOOKUP($AF25,$LOOKUP_HTS_C,3)*$AF25
26	(($S-1)*$BI26+$AD26*($AG26+$AI26)+$S*($AS26+$AU26)/2)/12+($A*$S+$AP26+$BE26)	2	@VLOOKUP($AF26,$A_ORIGINAL,6)*CN26	@IF($BO26="n/a",0,$BO26)	@EXP((-15)*($AF26)^2)	@VLOOKUP($AF26,$LOOKUP_HTS_C,3)*$AF26
27	(($S-1)*$BI27+$AD27*($AO27+$AI27)+$S*($AS27+$AU27)/2)/12+($A*$S+$AP27+$BE27)	2	@VLOOKUP($AF27,$A_ORIGINAL,6)*CN27	@IF($BO27="n/a",0,$BO27)	@EXP((-15)*($AF27)^2)	@VLOOKUP($AF27,$LOOKUP_HTS_C,3)*$AF27
28	(($S-1)*$BI28+$AD28*($AG28+$AI28)+$S*($AS28+$AU28)/2)/12+($A*$S+$AP28+$BE28)	2	@VLOOKUP($AF28,$A_ORIGINAL,6)*CN28	@IF($BO28="n/a",0,$BO28)	@EXP((-15)*($AF28)^2)	@VLOOKUP($AF28,$LOOKUP_HTS_C,3)*$AF28
29	(($S-1)*$BI29+$AD29*($AG29+$AI29)+$S*($AS29+$AU29)/2)/12+($A*$S+$AP29+$BE29)	2	@VLOOKUP($AF29,$A_ORIGINAL,6)*CN29	@IF($BO29="n/a",0,$BO29)	@EXP((-15)*($AF29)^2)	@VLOOKUP($AF29,$LOOKUP_HTS_C,3)*$AF29
30	(($S-1)*$BI30+$AD30*($AO30+$AI30)+$S*($AS30+$AU30)/2)/12+($A*$S+$AP30+$BE30)	2	@VLOOKUP($AF30,$A_ORIGINAL,6)*CN30	@IF($BO30="n/a",0,$BO30)	@EXP((-15)*($AF30)^2)	@VLOOKUP($AF30,$LOOKUP_HTS_C,3)*$AF30
31	(($S-1)*$BI31+$AD31*($AG31+$AI31)+$S*($AS31+$AU31)/2)/12+($A*$S+$AP31+$BE31)	2	@VLOOKUP($AF31,$A_ORIGINAL,6)*CN31	@IF($BO31="n/a",0,$BO31)	@EXP((-15)*($AF31)^2)	@VLOOKUP($AF31,$LOOKUP_HTS_C,3)*$AF31
32	(($S-1)*$BI32+$AD32*($AO32+$AI32)+$S*($AS32+$AU32)/2)/12+($A*$S+$AP32+$BE32)	2	@VLOOKUP($AF32,$A_ORIGINAL,6)*CN32	@IF($BO32="n/a",0,$BO32)	@EXP((-15)*($AF32)^2)	@VLOOKUP($AF32,$LOOKUP_HTS_C,3)*$AF32
33	(($S-1)*$BI33+$AD33*($AO33+$AI33)+$S*($AS33+$AU33)/2)/12+($A*$S+$AP33+$BE33)	2	@VLOOKUP($AF33,$A_ORIGINAL,6)*CN33	@IF($BO33="n/a",0,$BO33)	@EXP((-15)*($AF33)^2)	@VLOOKUP($AF33,$LOOKUP_HTS_C,3)*$AF33
34	(($S-1)*$BI34+$AD34*($AO34+$AI34)+$S*($AS34+$AU34)/2)/12+($A*$S+$AP34+$BE34)	2	@VLOOKUP($AF34,$A_ORIGINAL,6)*CN34	@IF($BO34="n/a",0,$BO34)	@EXP((-15)*($AF34)^2)	@VLOOKUP($AF34,$LOOKUP_HTS_C,3)*$AF34
35	(($S-1)*$BI35+$AD35*($AO35+$AI35)+$S*($AS35+$AU35)/2)/12+($A*$S+$AP35+$BE35)	2	@VLOOKUP($AF35,$A_ORIGINAL,6)*CN35	@IF($BO35="n/a",0,$BO35)	@EXP((-15)*($AF35)^2)	@VLOOKUP($AF35,$LOOKUP_HTS_C,3)*$AF35
36	(($S-1)*$BI36+$AD36*($AO36+$AI36)+$S*($AS36+$AU36)/2)/12+($A*$S+$AP36+$BE36)	2	@VLOOKUP($AF36,$A_ORIGINAL,6)*CN36	@IF($BO36="n/a",0,$BO36)	@EXP((-15)*($AF36)^2)	@VLOOKUP($AF36,$LOOKUP_HTS_C,3)*$AF36
37	(($S-1)*$BI37+$AD37*($AO37+$AI37)+$S*($AS37+$AU37)/2)/12+($A*$S+$AP37+$BE37)	2	@VLOOKUP($AF37,$A_ORIGINAL,6)*CN37	@IF($BO37="n/a",0,$BO37)	@EXP((-15)*($AF37)^2)	@VLOOKUP($AF37,$LOOKUP_HTS_C,3)*$AF37
38	(($S-1)*$BI38+$AD38*($AO38+$AI38)+$S*($AS38+$AU38)/2)/12+($A*$S+$AP38+$BE38)	2	@VLOOKUP($AF38,$A_ORIGINAL,6)*CN38	@IF($BO38="n/a",0,$BO38)	@EXP((-15)*($AF38)^2)	@VLOOKUP($AF38,$LOOKUP_HTS_C,3)*$AF38
39	(($S-1)*$BI39+$AD39*($AO39+$AI39)+$S*($AS39+$AU39)/2)/12+($A*$S+$AP39+$BE39)	2	@VLOOKUP($AF39,$A_ORIGINAL,6)*CN39	@IF($BO39="n/a",0,$BO39)	@EXP((-15)*($AF39)^2)	@VLOOKUP($AF39,$LOOKUP_HTS_C,3)*$AF39
40	(($S-1)*$BI40+$AD40*($AO40+$AI40)+$S*($AS40+$AU40)/2)/12+($A*$S+$AP40+$BE40)	2	@VLOOKUP($AF40,$A_ORIGINAL,6)*CN40	@IF($BO40="n/a",0,$BO40)	@EXP((-15)*($AF40)^2)	@VLOOKUP($AF40,$LOOKUP_HTS_C,3)*$AF40
41	(($S-1)*$BI41+$AD41*($AG41+$AI41)+$S*($AS41+$AU41)/2)/12+($A*$S+$AP41+$BE41)	2	@VLOOKUP($AF41,$A_ORIGINAL,6)*CN41	@IF($BO41="n/a",0,$BO41)	@EXP((-15)*($AF41)^2)	@VLOOKUP($AF41,$LOOKUP_HTS_C,3)*$AF41
42	(($S-1)*$BI42+$AD42*($AO42+$AI42)+$S*($AS42+$AU42)/2)/12+($A*$S+$AP42+$BE42)	2	@VLOOKUP($AF42,$A_ORIGINAL,6)*CN42	@IF($BO42="n/a",0,$BO42)	@EXP((-15)*($AF42)^2)	@VLOOKUP($AF42,$LOOKUP_HTS_C,3)*$AF42
43	(($S-1)*$BI43+$AD43*($AO43+$AI43)+$S*($AS43+$AU43)/2)/12+($A*$S+$AP43+$BE43)	2	@VLOOKUP($AF43,$A_ORIGINAL,6)*CN43	@IF($BO43="n/a",0,$BO43)	@EXP((-15)*($AF43)^2)	@VLOOKUP($AF43,$LOOKUP_HTS_C,3)*$AF43
44	(($S-1)*$BI44+$AD44*($AG44+$AI44)+$S*($AS44+$AU44)/2)/12+($A*$S+$AP44+$BE44)	3	@VLOOKUP($AF44,$A_ORIGINAL,6)*CN44	@IF($BO44="n/a",0,$BO44)	@EXP((-15)*($AF44)^2)	@VLOOKUP($AF44,$LOOKUP_HTS_C,3)*$AF44
45	(($S-1)*$BI45+$AD45*($AO45+$AI45)+$S*($AS45+$AU45)/2)/12+($A*$S+$AP45+$BE45)	4	@VLOOKUP($AF45,$A_ORIGINAL,6)*CN45	@IF($BO45="n/a",0,$BO45)	@EXP((-15)*($AF45)^2)	@VLOOKUP($AF45,$LOOKUP_HTS_C,3)*$AF45
46	(($S-1)*$BI46+$AD46*($AG46+$AI46)+$S*($AS46+$AU46)/2)/12+($A*$S+$AP46+$BE46)	5	@VLOOKUP($AF46,$A_ORIGINAL,6)*CN46	@IF($BO46="n/a",0,$BO46)	@EXP((-15)*($AF46)^2)	@VLOOKUP($AF46,$LOOKUP_HTS_C,3)*$AF46
47	(($S-1)*$BI47+$AD47*($AG47+$AI47)+$S*($AS47+$AU47)/2)/12+($A*$S+$AP47+$BE47)	6	@VLOOKUP($AF47,$A_ORIGINAL,6)*CN47	@IF($BO47="n/a",0,$BO47)	@EXP((-15)*($AF47)^2)	@VLOOKUP($AF47,$LOOKUP_HTS_C,3)*$AF47
48	(($S-1)*$BI48+$AD48*($AO48+$AI48)+$S*($AS48+$AU48)/2)/12+($A*$S+$AP48+$BE48)	3	@VLOOKUP($AF48,$A_ORIGINAL,6)*CN48	@IF($BO48="n/a",0,$BO48)	@EXP((-15)*($AF48)^2)	@VLOOKUP($AF48,$LOOKUP_HTS_C,3)*$AF48
49	(($S-1)*$BI49+$AD49*($AO49+$AI49)+$S*($AS49+$AU49)/2)/12+($A*$S+$AP49+$BE49)	4	@VLOOKUP($AF49,$A_ORIGINAL,6)*CN49	@IF($BO49="n/a",0,$BO49)	@EXP((-15)*($AF49)^2)	@VLOOKUP($AF49,$LOOKUP_HTS_C,3)*$AF49
50	(($S-1)*$BI50+$AD50*($AO50+$AI50)+$S*($AS50+$AU50)/2)/12+($A*$S+$AP50+$BE50)	5	@VLOOKUP($AF50,$A_ORIGINAL,6)*CN50	@IF($BO50="n/a",0,$BO50)	@EXP((-15)*($AF50)^2)	@VLOOKUP($AF50,$LOOKUP_HTS_C,3)*$AF50
51	(($S-1)*$BI51+$AD51*($AO51+$AI51)+$S*($AS51+$AU51)/2)/12+($A*$S+$AP51+$BE51)	6	@VLOOKUP($AF51,$A_ORIGINAL,6)*CN51	@IF($BO51="n/a",0,$BO51)	@EXP((-15)*($AF51)^2)	@VLOOKUP($AF51,$LOOKUP_HTS_C,3)*$AF51
52	(($S-1)*$BI52+$AD52*($AG52+$AI52)+$S*($AS52+$AU52)/2)/12+($A*$S+$AP52+$BE52)		@VLOOKUP($AF52,$A_ORIGINAL,6)*CN52	@IF($BO52="n/a",0,$BO52)	@EXP((-15)*($AF52)^2)	@VLOOKUP($AF52,$LOOKUP_HTS_C,3)*$AF52
53	(($S-1)*$BI53+$AD53*($AO53+$AI53)+$S*($AS53+$AU53)/2)/12+($A*$S+$AP53+$BE53)		@VLOOKUP($AF53,$A_ORIGINAL,6)*CN53	@IF($BO53="n/a",0,$BO53)	@EXP((-15)*($AF53)^2)	@VLOOKUP($AF53,$LOOKUP_HTS_C,3)*$AF53
54	(($S-1)*$BI54+$AD54*($AG54+$AI54)+$S*($AS54+$AU54)/2)/12+($A*$S+$AP54+$BE54)		@VLOOKUP($AF54,$A_ORIGINAL,6)*CN54	@IF($BO54="n/a",0,$BO54)	@EXP((-15)*($AF54)^2)	@VLOOKUP($AF54,$LOOKUP_HTS_C,3)*$AF54
55	(($S-1)*$BI55+$AD55*($AO55+$AI55)+$S*($AS55+$AU55)/2)/12+($A*$S+$AP55+$BE55)		@VLOOKUP($AF55,$A_ORIGINAL,6)*CN55	@IF($BO55="n/a",0,$BO55)	@EXP((-15)*($AF55)^2)	@VLOOKUP($AF55,$LOOKUP_HTS_C,3)*$AF55
56	(($S-1)*$BI56+$AD56*($AO56+$AI56)+$S*($AS56+$AU56)/2)/12+($A*$S+$AP56+$BE56)		@VLOOKUP($AF56,$A_ORIGINAL,6)*CN56	@IF($BO56="n/a",0,$BO56)	@EXP((-15)*($AF56)^2)	@VLOOKUP($AF56,$LOOKUP_HTS_C,3)*$AF56
57	CM12)		@SUM(CP56 CP12)			

A	CT	CU	CV	CW	CX	CY
1						
2						
3						
4						
5						
6						
7		Auto Weld	Auto Weld	Auto Weld	Auto Weld	Man Weld
8	Distortion	- Fillet	- Fillet	- Butt	- Butt	- Fillet Down
9						
10						
11						
12	6.5*$CQ12*$CS12/$RATE	@IF($BM12=1,2*$AP12+2*$BE12,0)	@VLOOKUP($AF12,$A_ORIGINAL,7)*$CU12	@IF($BM12=1,2*$BN12,0)	@VLOOKUP($AF12,$A_ORIGINAL,8)*$CW12	@IF($BM12=2,2*$AP12+2*$BE12,0)
13	6.5*$CQ13*$CS13/$RATE	@IF($BM13=1,2*$AP13+2*$BE13,0)	@VLOOKUP($AF13,$A_ORIGINAL,7)*$CU13	@IF($BM13=1,2*$BN13,0)	@VLOOKUP($AF13,$A_ORIGINAL,8)*$CW13	@IF($BM13=2,2*$AP13+2*$BE13,0)
14	6.5*$CQ14*$CS14/$RATE	@IF($BM14=1,2*$AP14+2*$BE14,0)	@VLOOKUP($AF14,$A_ORIGINAL,7)*$CU14	@IF($BM14=1,2*$BN14,0)	@VLOOKUP($AF14,$A_ORIGINAL,8)*$CW14	@IF($BM14=2,2*$AP14+2*$BE14,0)
15	6.5*$CQ15*$CS15/$RATE	@IF($BM15=1,2*$AP15+2*$BE15,0)	@VLOOKUP($AF15,$A_ORIGINAL,7)*$CU15	@IF($BM15=1,2*$BN15,0)	@VLOOKUP($AF15,$A_ORIGINAL,8)*$CW15	@IF($BM15=2,2*$AP15+2*$BE15,0)
16	6.5*$CQ16*$CS16/$RATE	@IF($BM16=1,2*$AP16+2*$BE16,0)	@VLOOKUP($AF16,$A_ORIGINAL,7)*$CU16	@IF($BM16=1,2*$BN16,0)	@VLOOKUP($AF16,$A_ORIGINAL,8)*$CW16	@IF($BM16=2,2*$AP16+2*$BE16,0)
17	6.5*$CQ17*$CS17/$RATE	@IF($BM17=1,2*$AP17+2*$BE17,0)	@VLOOKUP($AF17,$A_ORIGINAL,7)*$CU17	@IF($BM17=1,2*$BN17,0)	@VLOOKUP($AF17,$A_ORIGINAL,8)*$CW17	@IF($BM17=2,2*$AP17+2*$BE17,0)
18	6.5*$CQ18*$CS18/$RATE	@IF($BM18=1,2*$AP18+2*$BE18,0)	@VLOOKUP($AF18,$A_ORIGINAL,7)*$CU18	@IF($BM18=1,2*$BN18,0)	@VLOOKUP($AF18,$A_ORIGINAL,8)*$CW18	@IF($BM18=2,2*$AP18+2*$BE18,0)
19	6.5*$CQ19*$CS19/$RATE	@IF($BM19=1,2*$AP19+2*$BE19,0)	@VLOOKUP($AF19,$A_ORIGINAL,7)*$CU19	@IF($BM19=1,2*$BN19,0)	@VLOOKUP($AF19,$A_ORIGINAL,8)*$CW19	@IF($BM19=2,2*$AP19+2*$BE19,0)
20	6.5*$CQ20*$CS20/$RATE	@IF($BM20=1,2*$AP20+2*$BE20,0)	@VLOOKUP($AF20,$A_ORIGINAL,7)*$CU20	@IF($BM20=1,2*$BN20,0)	@VLOOKUP($AF20,$A_ORIGINAL,8)*$CW20	@IF($BM20=2,2*$AP20+2*$BE20,0)
21	6.5*$CQ21*$CS21/$RATE	@IF($BM21=1,2*$AP21+2*$BE21,0)	@VLOOKUP($AF21,$A_ORIGINAL,7)*$CU21	@IF($BM21=1,2*$BN21,0)	@VLOOKUP($AF21,$A_ORIGINAL,8)*$CW21	@IF($BM21=2,2*$AP21+2*$BE21,0)
22	6.5*$CQ22*$CS22/$RATE	@IF($BM22=1,2*$AP22+2*$BE22,0)	@VLOOKUP($AF22,$A_ORIGINAL,7)*$CU22	@IF($BM22=1,2*$BN22,0)	@VLOOKUP($AF22,$A_ORIGINAL,8)*$CW22	@IF($BM22=2,2*$AP22+2*$BE22,0)
23	6.5*$CQ23*$CS23/$RATE	@IF($BM23=1,2*$AP23+2*$BE23,0)	@VLOOKUP($AF23,$A_ORIGINAL,7)*$CU23	@IF($BM23=1,2*$BN23,0)	@VLOOKUP($AF23,$A_ORIGINAL,8)*$CW23	@IF($BM23=2,2*$AP23+2*$BE23,0)
24	6.5*$CQ24*$CS24/$RATE	@IF($BM24=1,2*$AP24+2*$BE24,0)	@VLOOKUP($AF24,$A_ORIGINAL,7)*$CU24	@IF($BM24=1,2*$BN24,0)	@VLOOKUP($AF24,$A_ORIGINAL,8)*$CW24	@IF($BM24=2,2*$AP24+2*$BE24,0)
25	6.5*$CQ25*$CS25/$RATE	@IF($BM25=1,2*$AP25+2*$BE25,0)	@VLOOKUP($AF25,$A_ORIGINAL,7)*$CU25	@IF($BM25=1,2*$BN25,0)	@VLOOKUP($AF25,$A_ORIGINAL,8)*$CW25	@IF($BM25=2,2*$AP25+2*$BE25,0)
26	6.5*$CQ26*$CS26/$RATE	@IF($BM26=1,2*$AP26+2*$BE26,0)	@VLOOKUP($AF26,$A_ORIGINAL,7)*$CU26	@IF($BM26=1,2*$BN26,0)	@VLOOKUP($AF26,$A_ORIGINAL,8)*$CW26	@IF($BM26=2,2*$AP26+2*$BE26,0)
27	6.5*$CQ27*$CS27/$RATE	@IF($BM27=1,2*$AP27+2*$BE27,0)	@VLOOKUP($AF27,$A_ORIGINAL,7)*$CU27	@IF($BM27=1,2*$BN27,0)	@VLOOKUP($AF27,$A_ORIGINAL,8)*$CW27	@IF($BM27=2,2*$AP27+2*$BE27,0)
28	6.5*$CQ28*$CS28/$RATE	@IF($BM28=1,2*$AP28+2*$BE28,0)	@VLOOKUP($AF28,$A_ORIGINAL,7)*$CU28	@IF($BM28=1,2*$BN28,0)	@VLOOKUP($AF28,$A_ORIGINAL,8)*$CW28	@IF($BM28=2,2*$AP28+2*$BE28,0)
29	6.5*$CQ29*$CS29/$RATE	@IF($BM29=1,2*$AP29+2*$BE29,0)	@VLOOKUP($AF29,$A_ORIGINAL,7)*$CU29	@IF($BM29=1,2*$BN29,0)	@VLOOKUP($AF29,$A_ORIGINAL,8)*$CW29	@IF($BM29=2,2*$AP29+2*$BE29,0)
30	6.5*$CQ30*$CS30/$RATE	@IF($BM30=1,2*$AP30+2*$BE30,0)	@VLOOKUP($AF30,$A_ORIGINAL,7)*$CU30	@IF($BM30=1,2*$BN30,0)	@VLOOKUP($AF30,$A_ORIGINAL,8)*$CW30	@IF($BM30=2,2*$AP30+2*$BE30,0)
31	6.5*$CQ31*$CS31/$RATE	@IF($BM31=1,2*$AP31+2*$BE31,0)	@VLOOKUP($AF31,$A_ORIGINAL,7)*$CU31	@IF($BM31=1,2*$BN31,0)	@VLOOKUP($AF31,$A_ORIGINAL,8)*$CW31	@IF($BM31=2,2*$AP31+2*$BE31,0)
32	6.5*$CQ32*$CS32/$RATE	@IF($BM32=1,2*$AP32+2*$BE32,0)	@VLOOKUP($AF32,$A_ORIGINAL,7)*$CU32	@IF($BM32=1,2*$BN32,0)	@VLOOKUP($AF32,$A_ORIGINAL,8)*$CW32	@IF($BM32=2,2*$AP32+2*$BE32,0)
33	6.5*$CQ33*$CS33/$RATE	@IF($BM33=1,2*$AP33+2*$BE33,0)	@VLOOKUP($AF33,$A_ORIGINAL,7)*$CU33	@IF($BM33=1,2*$BN33,0)	@VLOOKUP($AF33,$A_ORIGINAL,8)*$CW33	@IF($BM33=2,2*$AP33+2*$BE33,0)
34	6.5*$CQ34*$CS34/$RATE	@IF($BM34=1,2*$AP34+2*$BE34,0)	@VLOOKUP($AF34,$A_ORIGINAL,7)*$CU34	@IF($BM34=1,2*$BN34,0)	@VLOOKUP($AF34,$A_ORIGINAL,8)*$CW34	@IF($BM34=2,2*$AP34+2*$BE34,0)
35	6.5*$CQ35*$CS35/$RATE	@IF($BM35=1,2*$AP35+2*$BE35,0)	@VLOOKUP($AF35,$A_ORIGINAL,7)*$CU35	@IF($BM35=1,2*$BN35,0)	@VLOOKUP($AF35,$A_ORIGINAL,8)*$CW35	@IF($BM35=2,2*$AP35+2*$BE35,0)
36	6.5*$CQ36*$CS36/$RATE	@IF($BM36=1,2*$AP36+2*$BE36,0)	@VLOOKUP($AF36,$A_ORIGINAL,7)*$CU36	@IF($BM36=1,2*$BN36,0)	@VLOOKUP($AF36,$A_ORIGINAL,8)*$CW36	@IF($BM36=2,2*$AP36+2*$BE36,0)
37	6.5*$CQ37*$CS37/$RATE	@IF($BM37=1,2*$AP37+2*$BE37,0)	@VLOOKUP($AF37,$A_ORIGINAL,7)*$CU37	@IF($BM37=1,2*$BN37,0)	@VLOOKUP($AF37,$A_ORIGINAL,8)*$CW37	@IF($BM37=2,2*$AP37+2*$BE37,0)
38	6.5*$CQ38*$CS38/$RATE	@IF($BM38=1,2*$AP38+2*$BE38,0)	@VLOOKUP($AF38,$A_ORIGINAL,7)*$CU38	@IF($BM38=1,2*$BN38,0)	@VLOOKUP($AF38,$A_ORIGINAL,8)*$CW38	@IF($BM38=2,2*$AP38+2*$BE38,0)
39	6.5*$CQ39*$CS39/$RATE	@IF($BM39=1,2*$AP39+2*$BE39,0)	@VLOOKUP($AF39,$A_ORIGINAL,7)*$CU39	@IF($BM39=1,2*$BN39,0)	@VLOOKUP($AF39,$A_ORIGINAL,8)*$CW39	@IF($BM39=2,2*$AP39+2*$BE39,0)
40	6.5*$CQ40*$CS40/$RATE	@IF($BM40=1,2*$AP40+2*$BE40,0)	@VLOOKUP($AF40,$A_ORIGINAL,7)*$CU40	@IF($BM40=1,2*$BN40,0)	@VLOOKUP($AF40,$A_ORIGINAL,8)*$CW40	@IF($BM40=2,2*$AP40+2*$BE40,0)
41	6.5*$CQ41*$CS41/$RATE	@IF($BM41=1,2*$AP41+2*$BE41,0)	@VLOOKUP($AF41,$A_ORIGINAL,7)*$CU41	@IF($BM41=1,2*$BN41,0)	@VLOOKUP($AF41,$A_ORIGINAL,8)*$CW41	@IF($BM41=2,2*$AP41+2*$BE41,0)
42	6.5*$CQ42*$CS42/$RATE	@IF($BM42=1,2*$AP42+2*$BE42,0)	@VLOOKUP($AF42,$A_ORIGINAL,7)*$CU42	@IF($BM42=1,2*$BN42,0)	@VLOOKUP($AF42,$A_ORIGINAL,8)*$CW42	@IF($BM42=2,2*$AP42+2*$BE42,0)
43	6.5*$CQ43*$CS43/$RATE	@IF($BM43=1,2*$AP43+2*$BE43,0)	@VLOOKUP($AF43,$A_ORIGINAL,7)*$CU43	@IF($BM43=1,2*$BN43,0)	@VLOOKUP($AF43,$A_ORIGINAL,8)*$CW43	@IF($BM43=2,2*$AP43+2*$BE43,0)
44	6.5*$CQ44*$CS44/$RATE	@IF($BM44=1,2*$AP44+2*$BE44,0)	@VLOOKUP($AF44,$A_ORIGINAL,7)*$CU44	@IF($BM44=1,2*$BN44,0)	@VLOOKUP($AF44,$A_ORIGINAL,8)*$CW44	@IF($BM44=2,2*$AP44+2*$BE44,0)
45	6.5*$CQ45*$CS45/$RATE	@IF($BM45=1,2*$AP45+2*$BE45,0)	@VLOOKUP($AF45,$A_ORIGINAL,7)*$CU45	@IF($BM45=1,2*$BN45,0)	@VLOOKUP($AF45,$A_ORIGINAL,8)*$CW45	@IF($BM45=2,2*$AP45+2*$BE45,0)
46	6.5*$CQ46*$CS46/$RATE	@IF($BM46=1,2*$AP46+2*$BE46,0)	@VLOOKUP($AF46,$A_ORIGINAL,7)*$CU46	@IF($BM46=1,2*$BN46,0)	@VLOOKUP($AF46,$A_ORIGINAL,8)*$CW46	@IF($BM46=2,2*$AP46+2*$BE46,0)
47	6.5*$CQ47*$CS47/$RATE	@IF($BM47=1,2*$AP47+2*$BE47,0)	@VLOOKUP($AF47,$A_ORIGINAL,7)*$CU47	@IF($BM47=1,2*$BN47,0)	@VLOOKUP($AF47,$A_ORIGINAL,8)*$CW47	@IF($BM47=2,2*$AP47+2*$BE47,0)
48	6.5*$CQ48*$CS48/$RATE	@IF($BM48=1,2*$AP48+2*$BE48,0)	@VLOOKUP($AF48,$A_ORIGINAL,7)*$CU48	@IF($BM48=1,2*$BN48,0)	@VLOOKUP($AF48,$A_ORIGINAL,8)*$CW48	@IF($BM48=2,2*$AP48+2*$BE48,0)
49	6.5*$CQ49*$CS49/$RATE	@IF($BM49=1,2*$AP49+2*$BE49,0)	@VLOOKUP($AF49,$A_ORIGINAL,7)*$CU49	@IF($BM49=1,2*$BN49,0)	@VLOOKUP($AF49,$A_ORIGINAL,8)*$CW49	@IF($BM49=2,2*$AP49+2*$BE49,0)
50	6.5*$CQ50*$CS50/$RATE	@IF($BM50=1,2*$AP50+2*$BE50,0)	@VLOOKUP($AF50,$A_ORIGINAL,7)*$CU50	@IF($BM50=1,2*$BN50,0)	@VLOOKUP($AF50,$A_ORIGINAL,8)*$CW50	@IF($BM50=2,2*$AP50+2*$BE50,0)
51	6.5*$CQ51*$CS51/$RATE	@IF($BM51=1,2*$AP51+2*$BE51,0)	@VLOOKUP($AF51,$A_ORIGINAL,7)*$CU51	@IF($BM51=1,2*$BN51,0)	@VLOOKUP($AF51,$A_ORIGINAL,8)*$CW51	@IF($BM51=2,2*$AP51+2*$BE51,0)
52	6.5*$CQ52*$CS52/$RATE	@IF($BM52=1,2*$AP52+2*$BE52,0)	@VLOOKUP($AF52,$A_ORIGINAL,7)*$CU52	@IF($BM52=1,2*$BN52,0)	@VLOOKUP($AF52,$A_ORIGINAL,8)*$CW52	@IF($BM52=2,2*$AP52+2*$BE52,0)
53	6.5*$CQ53*$CS53/$RATE	@IF($BM53=1,2*$AP53+2*$BE53,0)	@VLOOKUP($AF53,$A_ORIGINAL,7)*$CU53	@IF($BM53=1,2*$BN53,0)	@VLOOKUP($AF53,$A_ORIGINAL,8)*$CW53	@IF($BM53=2,2*$AP53+2*$BE53,0)
54	6.5*$CQ54*$CS54/$RATE	@IF($BM54=1,2*$AP54+2*$BE54,0)	@VLOOKUP($AF54,$A_ORIGINAL,7)*$CU54	@IF($BM54=1,2*$BN54,0)	@VLOOKUP($AF54,$A_ORIGINAL,8)*$CW54	@IF($BM54=2,2*$AP54+2*$BE54,0)
55	6.5*$CQ55*$CS55/$RATE	@IF($BM55=1,2*$AP55+2*$BE55,0)	@VLOOKUP($AF55,$A_ORIGINAL,7)*$CU55	@IF($BM55=1,2*$BN55,0)	@VLOOKUP($AF55,$A_ORIGINAL,8)*$CW55	@IF($BM55=2,2*$AP55+2*$BE55,0)
56	6.5*$CQ56*$CS56/$RATE	@IF($BM56=1,2*$AP56+2*$BE56,0)	@VLOOKUP($AF56,$A_ORIGINAL,7)*$CU56	@IF($BM56=1,2*$BN56,0)	@VLOOKUP($AF56,$A_ORIGINAL,8)*$CW56	@IF($BM56=2,2*$AP56+2*$BE56,0)
57	@SUM(CT56..CT12)		@SUM(CV56..CV12)		@SUM(CX56..CX12)	

A	CZ	DA	DB
1			
2			
3			
4			
5			
6			
7	Man Weld	Man Weld	Man Weld
8	- Fillet Down	- Butt Down	- Butt Down
9			
10			
11			
12	@VLOOKUP($AF12,$B_ORIGINAL,1)*$CY12	@IF($BM12=2,2*$BN12,0)+@IF($BL12=1,2*($BI12+$S*$AD12*($AG12+$AI12)+$S*(AS12+AU12))/12,0)	@VLOOKUP($AF12,$B_ORIGINAL,4)*$DA12
13	@VLOOKUP($AF13,$B_ORIGINAL,1)*$CY13	@IF($BM13=2,2*$BN13,0)+@IF($BL13=1,2*($BI13+$S*$AD13*($AG13+$AI13)+$S*(AS13+AU13))/12,0)	@VLOOKUP($AF13,$B_ORIGINAL,4)*$DA13
14	@VLOOKUP($AF14,$B_ORIGINAL,1)*$CY14	@IF($BM14=2,2*$BN14,0)+@IF($BL14=1,2*($BI14+$S*$AD14*($AG14+$AI14)+$S*(AS14+AU14))/12,0)	@VLOOKUP($AF14,$B_ORIGINAL,4)*$DA14
15	@VLOOKUP($AF15,$B_ORIGINAL,1)*$CY15	@IF($BM15=2,2*$BN15,0)+@IF($BL15=1,2*($BI15+$S*$AD15*($AG15+$AI15)+$S*(AS15+AU15))/12,0)	@VLOOKUP($AF15,$B_ORIGINAL,4)*$DA15
16	@VLOOKUP($AF16,$B_ORIGINAL,1)*$CY16	@IF($BM16=2,2*$BN16,0)+@IF($BL16=1,2*($BI16+$S*$AD16*($AG16+$AI16)+$S*(AS16+AU16))/12,0)	@VLOOKUP($AF16,$B_ORIGINAL,4)*$DA16
17	@VLOOKUP($AF17,$B_ORIGINAL,1)*$CY17	@IF($BM17=2,2*$BN17,0)+@IF($BL17=1,2*($BI17+$S*$AD17*($AG17+$AI17)+$S*(AS17+AU17))/12,0)	@VLOOKUP($AF17,$B_ORIGINAL,4)*$DA17
18	@VLOOKUP($AF18,$B_ORIGINAL,1)*$CY18	@IF($BM18=2,2*$BN18,0)+@IF($BL18=1,2*($BI18+$S*$AD18*($AG18+$AI18)+$S*(AS18+AU18))/12,0)	@VLOOKUP($AF18,$B_ORIGINAL,4)*$DA18
19	@VLOOKUP($AF19,$B_ORIGINAL,1)*$CY19	@IF($BM19=2,2*$BN19,0)+@IF($BL19=1,2*($BI19+$S*$AD19*($AG19+$AI19)+$S*(AS19+AU19))/12,0)	@VLOOKUP($AF19,$B_ORIGINAL,4)*$DA19
20	@VLOOKUP($AF20,$B_ORIGINAL,1)*$CY20	@IF($BM20=2,2*$BN20,0)+@IF($BL20=1,2*($BI20+$S*$AD20*($AG20+$AI20)+$S*(AS20+AU20))/12,0)	@VLOOKUP($AF20,$B_ORIGINAL,4)*$DA20
21	@VLOOKUP($AF21,$B_ORIGINAL,1)*$CY21	@IF($BM21=2,2*$BN21,0)+@IF($BL21=1,2*($BI21+$S*$AD21*($AG21+$AI21)+$S*(AS21+AU21))/12,0)	@VLOOKUP($AF21,$B_ORIGINAL,4)*$DA21
22	@VLOOKUP($AF22,$B_ORIGINAL,1)*$CY22	@IF($BM22=2,2*$BN22,0)+@IF($BL22=1,2*($BI22+$S*$AD22*($AG22+$AI22)+$S*(AS22+AU22))/12,0)	@VLOOKUP($AF22,$B_ORIGINAL,4)*$DA22
23	@VLOOKUP($AF23,$B_ORIGINAL,1)*$CY23	@IF($BM23=2,2*$BN23,0)+@IF($BL23=1,2*($BI23+$S*$AD23*($AG23+$AI23)+$S*(AS23+AU23))/12,0)	@VLOOKUP($AF23,$B_ORIGINAL,4)*$DA23
24	@VLOOKUP($AF24,$B_ORIGINAL,1)*$CY24	@IF($BM24=2,2*$BN24,0)+@IF($BL24=1,2*($BI24+$S*$AD24*($AG24+$AI24)+$S*(AS24+AU24))/12,0)	@VLOOKUP($AF24,$B_ORIGINAL,4)*$DA24
25	@VLOOKUP($AF25,$B_ORIGINAL,1)*$CY25	@IF($BM25=2,2*$BN25,0)+@IF($BL25=1,2*($BI25+$S*$AD25*($AG25+$AI25)+$S*(AS25+AU25))/12,0)	@VLOOKUP($AF25,$B_ORIGINAL,4)*$DA25
26	@VLOOKUP($AF26,$B_ORIGINAL,1)*$CY26	@IF($BM26=2,2*$BN26,0)+@IF($BL26=1,2*($BI26+$S*$AD26*($AG26+$AI26)+$S*(AS26+AU26))/12,0)	@VLOOKUP($AF26,$B_ORIGINAL,4)*$DA26
27	@VLOOKUP($AF27,$B_ORIGINAL,1)*$CY27	@IF($BM27=2,2*$BN27,0)+@IF($BL27=1,2*($BI27+$S*$AD27*($AG27+$AI27)+$S*(AS27+AU27))/12,0)	@VLOOKUP($AF27,$B_ORIGINAL,4)*$DA27
28	@VLOOKUP($AF28,$B_ORIGINAL,1)*$CY28	@IF($BM28=2,2*$BN28,0)+@IF($BL28=1,2*($BI28+$S*$AD28*($AG28+$AI28)+$S*(AS28+AU28))/12,0)	@VLOOKUP($AF28,$B_ORIGINAL,4)*$DA28
29	@VLOOKUP($AF29,$B_ORIGINAL,1)*$CY29	@IF($BM29=2,2*$BN29,0)+@IF($BL29=1,2*($BI29+$S*$AD29*($AG29+$AI29)+$S*(AS29+AU29))/12,0)	@VLOOKUP($AF29,$B_ORIGINAL,4)*$DA29
30	@VLOOKUP($AF30,$B_ORIGINAL,1)*$CY30	@IF($BM30=2,2*$BN30,0)+@IF($BL30=1,2*($BI30+$S*$AD30*($AG30+$AI30)+$S*(AS30+AU30))/12,0)	@VLOOKUP($AF30,$B_ORIGINAL,4)*$DA30
31	@VLOOKUP($AF31,$B_ORIGINAL,1)*$CY31	@IF($BM31=2,2*$BN31,0)+@IF($BL31=1,2*($BI31+$S*$AD31*($AG31+$AI31)+$S*(AS31+AU31))/12,0)	@VLOOKUP($AF31,$B_ORIGINAL,4)*$DA31
32	@VLOOKUP($AF32,$B_ORIGINAL,1)*$CY32	@IF($BM32=2,2*$BN32,0)+@IF($BL32=1,2*($BI32+$S*$AD32*($AG32+$AI32)+$S*(AS32+AU32))/12,0)	@VLOOKUP($AF32,$B_ORIGINAL,4)*$DA32
33	@VLOOKUP($AF33,$B_ORIGINAL,1)*$CY33	@IF($BM33=2,2*$BN33,0)+@IF($BL33=1,2*($BI33+$S*$AD33*($AG33+$AI33)+$S*(AS33+AU33))/12,0)	@VLOOKUP($AF33,$B_ORIGINAL,4)*$DA33
34	@VLOOKUP($AF34,$B_ORIGINAL,1)*$CY34	@IF($BM34=2,2*$BN34,0)+@IF($BL34=1,2*($BI34+$S*$AD34*($AG34+$AI34)+$S*(AS34+AU34))/12,0)	@VLOOKUP($AF34,$B_ORIGINAL,4)*$DA34
35	@VLOOKUP($AF35,$B_ORIGINAL,1)*$CY35	@IF($BM35=2,2*$BN35,0)+@IF($BL35=1,2*($BI35+$S*$AD35*($AG35+$AI35)+$S*(AS35+AU35))/12,0)	@VLOOKUP($AF35,$B_ORIGINAL,4)*$DA35
36	@VLOOKUP($AF36,$B_ORIGINAL,1)*$CY36	@IF($BM36=2,2*$BN36,0)+@IF($BL36=1,2*($BI36+$S*$AD36*($AG36+$AI36)+$S*(AS36+AU36))/12,0)	@VLOOKUP($AF36,$B_ORIGINAL,4)*$DA36
37	@VLOOKUP($AF37,$B_ORIGINAL,1)*$CY37	@IF($BM37=2,2*$BN37,0)+@IF($BL37=1,2*($BI37+$S*$AD37*($AG37+$AI37)+$S*(AS37+AU37))/12,0)	@VLOOKUP($AF37,$B_ORIGINAL,4)*$DA37
38	@VLOOKUP($AF38,$B_ORIGINAL,1)*$CY38	@IF($BM38=2,2*$BN38,0)+@IF($BL38=1,2*($BI38+$S*$AD38*($AG38+$AI38)+$S*(AS38+AU38))/12,0)	@VLOOKUP($AF38,$B_ORIGINAL,4)*$DA38
39	@VLOOKUP($AF39,$B_ORIGINAL,1)*$CY39	@IF($BM39=2,2*$BN39,0)+@IF($BL39=1,2*($BI39+$S*$AD39*($AG39+$AI39)+$S*(AS39+AU39))/12,0)	@VLOOKUP($AF39,$B_ORIGINAL,4)*$DA39
40	@VLOOKUP($AF40,$B_ORIGINAL,1)*$CY40	@IF($BM40=2,2*$BN40,0)+@IF($BL40=1,2*($BI40+$S*$AD40*($AG40+$AI40)+$S*(AS40+AU40))/12,0)	@VLOOKUP($AF40,$B_ORIGINAL,4)*$DA40
41	@VLOOKUP($AF41,$B_ORIGINAL,1)*$CY41	@IF($BM41=2,2*$BN41,0)+@IF($BL41=1,2*($BI41+$S*$AD41*($AG41+$AI41)+$S*(AS41+AU41))/12,0)	@VLOOKUP($AF41,$B_ORIGINAL,4)*$DA41
42	@VLOOKUP($AF42,$B_ORIGINAL,1)*$CY42	@IF($BM42=2,2*$BN42,0)+@IF($BL42=1,2*($BI42+$S*$AD42*($AG42+$AI42)+$S*(AS42+AU42))/12,0)	@VLOOKUP($AF42,$B_ORIGINAL,4)*$DA42
43	@VLOOKUP($AF43,$B_ORIGINAL,1)*$CY43	@IF($BM43=2,2*$BN43,0)+@IF($BL43=1,2*($BI43+$S*$AD43*($AG43+$AI43)+$S*(AS43+AU43))/12,0)	@VLOOKUP($AF43,$B_ORIGINAL,4)*$DA43
44	@VLOOKUP($AF44,$B_ORIGINAL,1)*$CY44	@IF($BM44=2,2*$BN44,0)+@IF($BL44=1,2*($BI44+$S*$AD44*($AG44+$AI44)+$S*(AS44+AU44))/12,0)	@VLOOKUP($AF44,$B_ORIGINAL,4)*$DA44
45	@VLOOKUP($AF45,$B_ORIGINAL,1)*$CY45	@IF($BM45=2,2*$BN45,0)+@IF($BL45=1,2*($BI45+$S*$AD45*($AG45+$AI45)+$S*(AS45+AU45))/12,0)	@VLOOKUP($AF45,$B_ORIGINAL,4)*$DA45
46	@VLOOKUP($AF46,$B_ORIGINAL,1)*$CY46	@IF($BM46=2,2*$BN46,0)+@IF($BL46=1,2*($BI46+$S*$AD46*($AG46+$AI46)+$S*(AS46+AU46))/12,0)	@VLOOKUP($AF46,$B_ORIGINAL,4)*$DA46
47	@VLOOKUP($AF47,$B_ORIGINAL,1)*$CY47	@IF($BM47=2,2*$BN47,0)+@IF($BL47=1,2*($BI47+$S*$AD47*($AG47+$AI47)+$S*(AS47+AU47))/12,0)	@VLOOKUP($AF47,$B_ORIGINAL,4)*$DA47
48	@VLOOKUP($AF48,$B_ORIGINAL,1)*$CY48	@IF($BM48=2,2*$BN48,0)+@IF($BL48=1,2*($BI48+$S*$AD48*($AG48+$AI48)+$S*(AS48+AU48))/12,0)	@VLOOKUP($AF48,$B_ORIGINAL,4)*$DA48
49	@VLOOKUP($AF49,$B_ORIGINAL,1)*$CY49	@IF($BM49=2,2*$BN49,0)+@IF($BL49=1,2*($BI49+$S*$AD49*($AG49+$AI49)+$S*(AS49+AU49))/12,0)	@VLOOKUP($AF49,$B_ORIGINAL,4)*$DA49
50	@VLOOKUP($AF50,$B_ORIGINAL,1)*$CY50	@IF($BM50=2,2*$BN50,0)+@IF($BL50=1,2*($BI50+$S*$AD50*($AG50+$AI50)+$S*(AS50+AU50))/12,0)	@VLOOKUP($AF50,$B_ORIGINAL,4)*$DA50
51	@VLOOKUP($AF51,$B_ORIGINAL,1)*$CY51	@IF($BM51=2,2*$BN51,0)+@IF($BL51=1,2*($BI51+$S*$AD51*($AG51+$AI51)+$S*(AS51+AU51))/12,0)	@VLOOKUP($AF51,$B_ORIGINAL,4)*$DA51
52	@VLOOKUP($AF52,$B_ORIGINAL,1)*$CY52	@IF($BM52=2,2*$BN52,0)+@IF($BL52=1,2*($BI52+$S*$AD52*($AG52+$AI52)+$S*(AS52+AU52))/12,0)	@VLOOKUP($AF52,$B_ORIGINAL,4)*$DA52
53	@VLOOKUP($AF53,$B_ORIGINAL,1)*$CY53	@IF($BM53=2,2*$BN53,0)+@IF($BL53=1,2*($BI53+$S*$AD53*($AG53+$AI53)+$S*(AS53+AU53))/12,0)	@VLOOKUP($AF53,$B_ORIGINAL,4)*$DA53
54	@VLOOKUP($AF54,$B_ORIGINAL,1)*$CY54	@IF($BM54=2,2*$BN54,0)+@IF($BL54=1,2*($BI54+$S*$AD54*($AG54+$AI54)+$S*(AS54+AU54))/12,0)	@VLOOKUP($AF54,$B_ORIGINAL,4)*$DA54
55	@VLOOKUP($AF55,$B_ORIGINAL,1)*$CY55	@IF($BM55=2,2*$BN55,0)+@IF($BL55=1,2*($BI55+$S*$AD55*($AG55+$AI55)+$S*(AS55+AU55))/12,0)	@VLOOKUP($AF55,$B_ORIGINAL,4)*$DA55
56	@VLOOKUP($AF56,$B_ORIGINAL,1)*$CY56	@IF($BM56=2,2*$BN56,0)+@IF($BL56=1,2*($BI56+$S*$AD56*($AG56+$AI56)+$S*(AS56+AU56))/12,0)	@VLOOKUP($AF56,$B_ORIGINAL,4)*$DA56
57	@SUM(CZ56..CZ12)		@SUM(DB56..DB12)

A	DC	DD	DE
1			
2			
3			
4			
5			
6			
7	Man Weld	Man Weld	Man Weld
8	- Butt Vert	- Butt Vert	- Butt Ovhd
9			
10			
11			
12	@IF($BM12=2,@IF($BL12=2,2*($BI12+$S*$AD12*($AG12+$AI12)+$S*($AS12+$AU12))/12,0),0)	@VLOOKUP($AF12,$B_ORIGINAL,5)*$DC12	@IF($BM12=2,@IF($BL12=3,2*($BI12+$S*$AD12*($AG12+$AI12)+$S*($AS12+$AU12))/12,0),0)
13	@IF($BM13=2,@IF($BL13=2,2*($BI13+$S*$AD13*($AG13+$AI13)+$S*($AS13+$AU13))/12,0),0)	@VLOOKUP($AF13,$B_ORIGINAL,5)*$DC13	@IF($BM13=2,@IF($BL13=3,2*($BI13+$S*$AD13*($AG13+$AI13)+$S*($AS13+$AU13))/12,0),0)
14	@IF($BM14=2,@IF($BL14=2,2*($BI14+$S*$AD14*($AG14+$AI14)+$S*($AS14+$AU14))/12,0),0)	@VLOOKUP($AF14,$B_ORIGINAL,5)*$DC14	@IF($BM14=2,@IF($BL14=3,2*($BI14+$S*$AD14*($AG14+$AI14)+$S*($AS14+$AU14))/12,0),0)
15	@IF($BM15=2,@IF($BL15=2,2*($BI15+$S*$AD15*($AG15+$AI15)+$S*($AS15+$AU15))/12,0),0)	@VLOOKUP($AF15,$B_ORIGINAL,5)*$DC15	@IF($BM15=2,@IF($BL15=3,2*($BI15+$S*$AD15*($AG15+$AI15)+$S*($AS15+$AU15))/12,0),0)
16	@IF($BM16=2,@IF($BL16=2,2*($BI16+$S*$AD16*($AG16+$AI16)+$S*($AS16+$AU16))/12,0),0)	@VLOOKUP($AF16,$B_ORIGINAL,5)*$DC16	@IF($BM16=2,@IF($BL16=3,2*($BI16+$S*$AD16*($AG16+$AI16)+$S*($AS16+$AU16))/12,0),0)
17	@IF($BM17=2,@IF($BL17=2,2*($BI17+$S*$AD17*($AG17+$AI17)+$S*($AS17+$AU17))/12,0),0)	@VLOOKUP($AF17,$B_ORIGINAL,5)*$DC17	@IF($BM17=2,@IF($BL17=3,2*($BI17+$S*$AD17*($AG17+$AI17)+$S*($AS17+$AU17))/12,0),0)
18	@IF($BM18=2,@IF($BL18=2,2*($BI18+$S*$AD18*($AG18+$AI18)+$S*($AS18+$AU18))/12,0),0)	@VLOOKUP($AF18,$B_ORIGINAL,5)*$DC18	@IF($BM18=2,@IF($BL18=3,2*($BI18+$S*$AD18*($AG18+$AI18)+$S*($AS18+$AU18))/12,0),0)
19	@IF($BM19=2,@IF($BL19=2,2*($BI19+$S*$AD19*($AG19+$AI19)+$S*($AS19+$AU19))/12,0),0)	@VLOOKUP($AF19,$B_ORIGINAL,5)*$DC19	@IF($BM19=2,@IF($BL19=3,2*($BI19+$S*$AD19*($AG19+$AI19)+$S*($AS19+$AU19))/12,0),0)
20	@IF($BM20=2,@IF($BL20=2,2*($BI20+$S*$AD20*($AG20+$AI20)+$S*($AS20+$AU20))/12,0),0)	@VLOOKUP($AF20,$B_ORIGINAL,5)*$DC20	@IF($BM20=2,@IF($BL20=3,2*($BI20+$S*$AD20*($AG20+$AI20)+$S*($AS20+$AU20))/12,0),0)
21	@IF($BM21=2,@IF($BL21=2,2*($BI21+$S*$AD21*($AG21+$AI21)+$S*($AS21+$AU21))/12,0),0)	@VLOOKUP($AF21,$B_ORIGINAL,5)*$DC21	@IF($BM21=2,@IF($BL21=3,2*($BI21+$S*$AD21*($AG21+$AI21)+$S*($AS21+$AU21))/12,0),0)
22	@IF($BM22=2,@IF($BL22=2,2*($BI22+$S*$AD22*($AG22+$AI22)+$S*($AS22+$AU22))/12,0),0)	@VLOOKUP($AF22,$B_ORIGINAL,5)*$DC22	@IF($BM22=2,@IF($BL22=3,2*($BI22+$S*$AD22*($AG22+$AI22)+$S*($AS22+$AU22))/12,0),0)
23	@IF($BM23=2,@IF($BL23=2,2*($BI23+$S*$AD23*($AG23+$AI23)+$S*($AS23+$AU23))/12,0),0)	@VLOOKUP($AF23,$B_ORIGINAL,5)*$DC23	@IF($BM23=2,@IF($BL23=3,2*($BI23+$S*$AD23*($AG23+$AI23)+$S*($AS23+$AU23))/12,0),0)
24	@IF($BM24=2,@IF($BL24=2,2*($BI24+$S*$AD24*($AG24+$AI24)+$S*($AS24+$AU24))/12,0),0)	@VLOOKUP($AF24,$B_ORIGINAL,5)*$DC24	@IF($BM24=2,@IF($BL24=3,2*($BI24+$S*$AD24*($AG24+$AI24)+$S*($AS24+$AU24))/12,0),0)
25	@IF($BM25=2,@IF($BL25=2,2*($BI25+$S*$AD25*($AG25+$AI25)+$S*($AS25+$AU25))/12,0),0)	@VLOOKUP($AF25,$B_ORIGINAL,5)*$DC25	@IF($BM25=2,@IF($BL25=3,2*($BI25+$S*$AD25*($AG25+$AI25)+$S*($AS25+$AU25))/12,0),0)
26	@IF($BM26=2,@IF($BL26=2,2*($BI26+$S*$AD26*($AG26+$AI26)+$S*($AS26+$AU26))/12,0),0)	@VLOOKUP($AF26,$B_ORIGINAL,5)*$DC26	@IF($BM26=2,@IF($BL26=3,2*($BI26+$S*$AD26*($AG26+$AI26)+$S*($AS26+$AU26))/12,0),0)
27	@IF($BM27=2,@IF($BL27=2,2*($BI27+$S*$AD27*($AG27+$AI27)+$S*($AS27+$AU27))/12,0),0)	@VLOOKUP($AF27,$B_ORIGINAL,5)*$DC27	@IF($BM27=2,@IF($BL27=3,2*($BI27+$S*$AD27*($AG27+$AI27)+$S*($AS27+$AU27))/12,0),0)
28	@IF($BM28=2,@IF($BL28=2,2*($BI28+$S*$AD28*($AG28+$AI28)+$S*($AS28+$AU28))/12,0),0)	@VLOOKUP($AF28,$B_ORIGINAL,5)*$DC28	@IF($BM28=2,@IF($BL28=3,2*($BI28+$S*$AD28*($AG28+$AI28)+$S*($AS28+$AU28))/12,0),0)
29	@IF($BM29=2,@IF($BL29=2,2*($BI29+$S*$AD29*($AG29+$AI29)+$S*($AS29+$AU29))/12,0),0)	@VLOOKUP($AF29,$B_ORIGINAL,5)*$DC29	@IF($BM29=2,@IF($BL29=3,2*($BI29+$S*$AD29*($AG29+$AI29)+$S*($AS29+$AU29))/12,0),0)
30	@IF($BM30=2,@IF($BL30=2,2*($BI30+$S*$AD30*($AG30+$AI30)+$S*($AS30+$AU30))/12,0),0)	@VLOOKUP($AF30,$B_ORIGINAL,5)*$DC30	@IF($BM30=2,@IF($BL30=3,2*($BI30+$S*$AD30*($AG30+$AI30)+$S*($AS30+$AU30))/12,0),0)
31	@IF($BM31=2,@IF($BL31=2,2*($BI31+$S*$AD31*($AG31+$AI31)+$S*($AS31+$AU31))/12,0),0)	@VLOOKUP($AF31,$B_ORIGINAL,5)*$DC31	@IF($BM31=2,@IF($BL31=3,2*($BI31+$S*$AD31*($AG31+$AI31)+$S*($AS31+$AU31))/12,0),0)
32	@IF($BM32=2,@IF($BL32=2,2*($BI32+$S*$AD32*($AG32+$AI32)+$S*($AS32+$AU32))/12,0),0)	@VLOOKUP($AF32,$B_ORIGINAL,5)*$DC32	@IF($BM32=2,@IF($BL32=3,2*($BI32+$S*$AD32*($AG32+$AI32)+$S*($AS32+$AU32))/12,0),0)
33	@IF($BM33=2,@IF($BL33=2,2*($BI33+$S*$AD33*($AG33+$AI33)+$S*($AS33+$AU33))/12,0),0)	@VLOOKUP($AF33,$B_ORIGINAL,5)*$DC33	@IF($BM33=2,@IF($BL33=3,2*($BI33+$S*$AD33*($AG33+$AI33)+$S*($AS33+$AU33))/12,0),0)
34	@IF($BM34=2,@IF($BL34=2,2*($BI34+$S*$AD34*($AG34+$AI34)+$S*($AS34+$AU34))/12,0),0)	@VLOOKUP($AF34,$B_ORIGINAL,5)*$DC34	@IF($BM34=2,@IF($BL34=3,2*($BI34+$S*$AD34*($AG34+$AI34)+$S*($AS34+$AU34))/12,0),0)
35	@IF($BM35=2,@IF($BL35=2,2*($BI35+$S*$AD35*($AG35+$AI35)+$S*($AS35+$AU35))/12,0),0)	@VLOOKUP($AF35,$B_ORIGINAL,5)*$DC35	@IF($BM35=2,@IF($BL35=3,2*($BI35+$S*$AD35*($AG35+$AI35)+$S*($AS35+$AU35))/12,0),0)
36	@IF($BM36=2,@IF($BL36=2,2*($BI36+$S*$AD36*($AG36+$AI36)+$S*($AS36+$AU36))/12,0),0)	@VLOOKUP($AF36,$B_ORIGINAL,5)*$DC36	@IF($BM36=2,@IF($BL36=3,2*($BI36+$S*$AD36*($AG36+$AI36)+$S*($AS36+$AU36))/12,0),0)
37	@IF($BM37=2,@IF($BL37=2,2*($BI37+$S*$AD37*($AG37+$AI37)+$S*($AS37+$AU37))/12,0),0)	@VLOOKUP($AF37,$B_ORIGINAL,5)*$DC37	@IF($BM37=2,@IF($BL37=3,2*($BI37+$S*$AD37*($AG37+$AI37)+$S*($AS37+$AU37))/12,0),0)
38	@IF($BM38=2,@IF($BL38=2,2*($BI38+$S*$AD38*($AG38+$AI38)+$S*($AS38+$AU38))/12,0),0)	@VLOOKUP($AF38,$B_ORIGINAL,5)*$DC38	@IF($BM38=2,@IF($BL38=3,2*($BI38+$S*$AD38*($AG38+$AI38)+$S*($AS38+$AU38))/12,0),0)
39	@IF($BM39=2,@IF($BL39=2,2*($BI39+$S*$AD39*($AG39+$AI39)+$S*($AS39+$AU39))/12,0),0)	@VLOOKUP($AF39,$B_ORIGINAL,5)*$DC39	@IF($BM39=2,@IF($BL39=3,2*($BI39+$S*$AD39*($AG39+$AI39)+$S*($AS39+$AU39))/12,0),0)
40	@IF($BM40=2,@IF($BL40=2,2*($BI40+$S*$AD40*($AG40+$AI40)+$S*($AS40+$AU40))/12,0),0)	@VLOOKUP($AF40,$B_ORIGINAL,5)*$DC40	@IF($BM40=2,@IF($BL40=3,2*($BI40+$S*$AD40*($AG40+$AI40)+$S*($AS40+$AU40))/12,0),0)
41	@IF($BM41=2,@IF($BL41=2,2*($BI41+$S*$AD41*($AG41+$AI41)+$S*($AS41+$AU41))/12,0),0)	@VLOOKUP($AF41,$B_ORIGINAL,5)*$DC41	@IF($BM41=2,@IF($BL41=3,2*($BI41+$S*$AD41*($AG41+$AI41)+$S*($AS41+$AU41))/12,0),0)
42	@IF($BM42=2,@IF($BL42=2,2*($BI42+$S*$AD42*($AG42+$AI42)+$S*($AS42+$AU42))/12,0),0)	@VLOOKUP($AF42,$B_ORIGINAL,5)*$DC42	@IF($BM42=2,@IF($BL42=3,2*($BI42+$S*$AD42*($AG42+$AI42)+$S*($AS42+$AU42))/12,0),0)
43	@IF($BM43=2,@IF($BL43=2,2*($BI43+$S*$AD43*($AG43+$AI43)+$S*($AS43+$AU43))/12,0),0)	@VLOOKUP($AF43,$B_ORIGINAL,5)*$DC43	@IF($BM43=2,@IF($BL43=3,2*($BI43+$S*$AD43*($AG43+$AI43)+$S*($AS43+$AU43))/12,0),0)
44	@IF($BM44=2,@IF($BL44=2,2*($BI44+$S*$AD44*($AG44+$AI44)+$S*($AS44+$AU44))/12,0),0)	@VLOOKUP($AF44,$B_ORIGINAL,5)*$DC44	@IF($BM44=2,@IF($BL44=3,2*($BI44+$S*$AD44*($AG44+$AI44)+$S*($AS44+$AU44))/12,0),0)
45	@IF($BM45=2,@IF($BL45=2,2*($BI45+$S*$AD45*($AG45+$AI45)+$S*($AS45+$AU45))/12,0),0)	@VLOOKUP($AF45,$B_ORIGINAL,5)*$DC45	@IF($BM45=2,@IF($BL45=3,2*($BI45+$S*$AD45*($AG45+$AI45)+$S*($AS45+$AU45))/12,0),0)
46	@IF($BM46=2,@IF($BL46=2,2*($BI46+$S*$AD46*($AG46+$AI46)+$S*($AS46+$AU46))/12,0),0)	@VLOOKUP($AF46,$B_ORIGINAL,5)*$DC46	@IF($BM46=2,@IF($BL46=3,2*($BI46+$S*$AD46*($AG46+$AI46)+$S*($AS46+$AU46))/12,0),0)
47	@IF($BM47=2,@IF($BL47=2,2*($BI47+$S*$AD47*($AG47+$AI47)+$S*($AS47+$AU47))/12,0),0)	@VLOOKUP($AF47,$B_ORIGINAL,5)*$DC47	@IF($BM47=2,@IF($BL47=3,2*($BI47+$S*$AD47*($AG47+$AI47)+$S*($AS47+$AU47))/12,0),0)
48	@IF($BM48=2,@IF($BL48=2,2*($BI48+$S*$AD48*($AG48+$AI48)+$S*($AS48+$AU48))/12,0),0)	@VLOOKUP($AF48,$B_ORIGINAL,5)*$DC48	@IF($BM48=2,@IF($BL48=3,2*($BI48+$S*$AD48*($AG48+$AI48)+$S*($AS48+$AU48))/12,0),0)
49	@IF($BM49=2,@IF($BL49=2,2*($BI49+$S*$AD49*($AG49+$AI49)+$S*($AS49+$AU49))/12,0),0)	@VLOOKUP($AF49,$B_ORIGINAL,5)*$DC49	@IF($BM49=2,@IF($BL49=3,2*($BI49+$S*$AD49*($AG49+$AI49)+$S*($AS49+$AU49))/12,0),0)
50	@IF($BM50=2,@IF($BL50=2,2*($BI50+$S*$AD50*($AG50+$AI50)+$S*($AS50+$AU50))/12,0),0)	@VLOOKUP($AF50,$B_ORIGINAL,5)*$DC50	@IF($BM50=2,@IF($BL50=3,2*($BI50+$S*$AD50*($AG50+$AI50)+$S*($AS50+$AU50))/12,0),0)
51	@IF($BM51=2,@IF($BL51=2,2*($BI51+$S*$AD51*($AG51+$AI51)+$S*($AS51+$AU51))/12,0),0)	@VLOOKUP($AF51,$B_ORIGINAL,5)*$DC51	@IF($BM51=2,@IF($BL51=3,2*($BI51+$S*$AD51*($AG51+$AI51)+$S*($AS51+$AU51))/12,0),0)
52	@IF($BM52=2,@IF($BL52=2,2*($BI52+$S*$AD52*($AG52+$AI52)+$S*($AS52+$AU52))/12,0),0)	@VLOOKUP($AF52,$B_ORIGINAL,5)*$DC52	@IF($BM52=2,@IF($BL52=3,2*($BI52+$S*$AD52*($AG52+$AI52)+$S*($AS52+$AU52))/12,0),0)
53	@IF($BM53=2,@IF($BL53=2,2*($BI53+$S*$AD53*($AG53+$AI53)+$S*($AS53+$AU53))/12,0),0)	@VLOOKUP($AF53,$B_ORIGINAL,5)*$DC53	@IF($BM53=2,@IF($BL53=3,2*($BI53+$S*$AD53*($AG53+$AI53)+$S*($AS53+$AU53))/12,0),0)
54	@IF($BM54=2,@IF($BL54=2,2*($BI54+$S*$AD54*($AG54+$AI54)+$S*($AS54+$AU54))/12,0),0)	@VLOOKUP($AF54,$B_ORIGINAL,5)*$DC54	@IF($BM54=2,@IF($BL54=3,2*($BI54+$S*$AD54*($AG54+$AI54)+$S*($AS54+$AU54))/12,0),0)
55	@IF($BM55=2,@IF($BL55=2,2*($BI55+$S*$AD55*($AG55+$AI55)+$S*($AS55+$AU55))/12,0),0)	@VLOOKUP($AF55,$B_ORIGINAL,5)*$DC55	@IF($BM55=2,@IF($BL55=3,2*($BI55+$S*$AD55*($AG55+$AI55)+$S*($AS55+$AU55))/12,0),0)
56	@IF($BM56=2,@IF($BL56=2,2*($BI56+$S*$AD56*($AG56+$AI56)+$S*($AS56+$AU56))/12,0),0)	@VLOOKUP($AF56,$B_ORIGINAL,5)*$DC56	@IF($BM56=2,@IF($BL56=3,2*($BI56+$S*$AD56*($AG56+$AI56)+$S*($AS56+$AU56))/12,0),0)
57		@SUM(DD56..DD12)	

TEXT - Main Spreadsheet

A	DF	DG	DH	DI	DJ	DK	DL	DM
1								
2								
3								
4								
5								
6								
7	Main Weld							
8	- Butt Ovhd	Marking		Store		Transport		Lift
9								
10								
11								
12	@VLOOKUP($AF12,$B_ORIGINAL,6)*$DE12	+$AD12+$BJ12+2*$S	0.1*$DG12*(0.85+0.15*$NUM/30)	+$AD12+$BJ12+2*$S	0.1*$DI12*(0.5+0.5*$NUM/30)	+$AD12+$BJ12+2*$S	0.5*$DK12*(0.65+0.35*$NUM/30)	+$AD12+$BJ12+2*$S
13	@VLOOKUP($AF13,$B_ORIGINAL,6)*$DE13	+$AD13+$BJ13+2*$S	0.1*$DG13*(0.85+0.15*$NUM/30)	+$AD13+$BJ13+2*$S	0.1*$DI13*(0.5+0.5*$NUM/30)	+$AD13+$BJ13+2*$S	0.5*$DK13*(0.65+0.35*$NUM/30)	+$AD13+$BJ13+2*$S
14	@VLOOKUP($AF14,$B_ORIGINAL,6)*$DE14	+$AD14+$BJ14+2*$S	0.1*$DG14*(0.85+0.15*$NUM/30)	+$AD14+$BJ14+2*$S	0.1*$DI14*(0.5+0.5*$NUM/30)	+$AD14+$BJ14+2*$S	0.5*$DK14*(0.65+0.35*$NUM/30)	+$AD14+$BJ14+2*$S
15	@VLOOKUP($AF15,$B_ORIGINAL,6)*$DE15	+$AD15+$BJ15+2*$S	0.1*$DG15*(0.85+0.15*$NUM/30)	+$AD15+$BJ15+2*$S	0.1*$DI15*(0.5+0.5*$NUM/30)	+$AD15+$BJ15+2*$S	0.5*$DK15*(0.65+0.35*$NUM/30)	+$AD15+$BJ15+2*$S
16	@VLOOKUP($AF16,$B_ORIGINAL,6)*$DE16	+$AD16+$BJ16+2*$S	0.1*$DG16*(0.85+0.15*$NUM/30)	+$AD16+$BJ16+2*$S	0.1*$DI16*(0.5+0.5*$NUM/30)	+$AD16+$BJ16+2*$S	0.5*$DK16*(0.65+0.35*$NUM/30)	+$AD16+$BJ16+2*$S
17	@VLOOKUP($AF17,$B_ORIGINAL,6)*$DE17	+$AD17+$BJ17+2*$S	0.1*$DG17*(0.85+0.15*$NUM/30)	+$AD17+$BJ17+2*$S	0.1*$DI17*(0.5+0.5*$NUM/30)	+$AD17+$BJ17+2*$S	0.5*$DK17*(0.65+0.35*$NUM/30)	+$AD17+$BJ17+2*$S
18	@VLOOKUP($AF18,$B_ORIGINAL,6)*$DE18	+$AD18+$BJ18+2*$S	0.1*$DG18*(0.85+0.15*$NUM/30)	+$AD18+$BJ18+2*$S	0.1*$DI18*(0.5+0.5*$NUM/30)	+$AD18+$BJ18+2*$S	0.5*$DK18*(0.65+0.35*$NUM/30)	+$AD18+$BJ18+2*$S
19	@VLOOKUP($AF19,$B_ORIGINAL,6)*$DE19	+$AD19+$BJ19+2*$S	0.1*$DG19*(0.85+0.15*$NUM/30)	+$AD19+$BJ19+2*$S	0.1*$DI19*(0.5+0.5*$NUM/30)	+$AD19+$BJ19+2*$S	0.5*$DK19*(0.65+0.35*$NUM/30)	+$AD19+$BJ19+2*$S
20	@VLOOKUP($AF20,$B_ORIGINAL,6)*$DE20	+$AD20+$BJ20+2*$S	0.1*$DG20*(0.85+0.15*$NUM/30)	+$AD20+$BJ20+2*$S	0.1*$DI20*(0.5+0.5*$NUM/30)	+$AD20+$BJ20+2*$S	0.5*$DK20*(0.65+0.35*$NUM/30)	+$AD20+$BJ20+2*$S
21	@VLOOKUP($AF21,$B_ORIGINAL,6)*$DE21	+$AD21+$BJ21+2*$S	0.1*$DG21*(0.85+0.15*$NUM/30)	+$AD21+$BJ21+2*$S	0.1*$DI21*(0.5+0.5*$NUM/30)	+$AD21+$BJ21+2*$S	0.5*$DK21*(0.65+0.35*$NUM/30)	+$AD21+$BJ21+2*$S
22	@VLOOKUP($AF22,$B_ORIGINAL,6)*$DE22	+$AD22+$BJ22+2*$S	0.1*$DG22*(0.85+0.15*$NUM/30)	+$AD22+$BJ22+2*$S	0.1*$DI22*(0.5+0.5*$NUM/30)	+$AD22+$BJ22+2*$S	0.5*$DK22*(0.65+0.35*$NUM/30)	+$AD22+$BJ22+2*$S
23	@VLOOKUP($AF23,$B_ORIGINAL,6)*$DE23	+$AD23+$BJ23+2*$S	0.1*$DG23*(0.85+0.15*$NUM/30)	+$AD23+$BJ23+2*$S	0.1*$DI23*(0.5+0.5*$NUM/30)	+$AD23+$BJ23+2*$S	0.5*$DK23*(0.65+0.35*$NUM/30)	+$AD23+$BJ23+2*$S
24	@VLOOKUP($AF24,$B_ORIGINAL,6)*$DE24	+$AD24+$BJ24+2*$S	0.1*$DG24*(0.85+0.15*$NUM/30)	+$AD24+$BJ24+2*$S	0.1*$DI24*(0.5+0.5*$NUM/30)	+$AD24+$BJ24+2*$S	0.5*$DK24*(0.65+0.35*$NUM/30)	+$AD24+$BJ24+2*$S
25	@VLOOKUP($AF25,$B_ORIGINAL,6)*$DE25	+$AD25+$BJ25+$S	0.1*$DG25*(0.85+0.15*$NUM/30)	+$AD25+$BJ25+2*$S	0.1*$DI25*(0.5+0.5*$NUM/30)	+$AD25+$BJ25+2*$S	0.5*$DK25*(0.65+0.35*$NUM/30)	+$AD25+$BJ25+2*$S
26	@VLOOKUP($AF26,$B_ORIGINAL,6)*$DE26	+$AD26+$BJ26+$S	0.1*$DG26*(0.85+0.15*$NUM/30)	+$AD26+$BJ26+2*$S	0.1*$DI26*(0.5+0.5*$NUM/30)	+$AD26+$BJ26+2*$S	0.5*$DK26*(0.65+0.35*$NUM/30)	+$AD26+$BJ26+2*$S
27	@VLOOKUP($AF27,$B_ORIGINAL,6)*$DE27	+$AD27+$BJ27+$S	0.1*$DG27*(0.85+0.15*$NUM/30)	+$AD27+$BJ27+2*$S	0.1*$DI27*(0.5+0.5*$NUM/30)	+$AD27+$BJ27+2*$S	0.5*$DK27*(0.65+0.35*$NUM/30)	+$AD27+$BJ27+2*$S
28	@VLOOKUP($AF28,$B_ORIGINAL,6)*$DE28	+$AD28+$BJ28+$S	0.1*$DG28*(0.85+0.15*$NUM/30)	+$AD28+$BJ28+2*$S	0.1*$DI28*(0.5+0.5*$NUM/30)	+$AD28+$BJ28+2*$S	0.5*$DK28*(0.65+0.35*$NUM/30)	+$AD28+$BJ28+2*$S
29	@VLOOKUP($AF29,$B_ORIGINAL,6)*$DE29	+$AD29+$BJ29+$S	0.1*$DG29*(0.85+0.15*$NUM/30)	+$AD29+$BJ29+2*$S	0.1*$DI29*(0.5+0.5*$NUM/30)	+$AD29+$BJ29+2*$S	0.5*$DK29*(0.65+0.35*$NUM/30)	+$AD29+$BJ29+2*$S
30	@VLOOKUP($AF30,$B_ORIGINAL,6)*$DE30	+$AD30+$BJ30+2*$S	0.1*$DG30*(0.85+0.15*$NUM/30)	+$AD30+$BJ30+2*$S	0.1*$DI30*(0.5+0.5*$NUM/30)	+$AD30+$BJ30+2*$S	0.5*$DK30*(0.65+0.35*$NUM/30)	+$AD30+$BJ30+2*$S
31	@VLOOKUP($AF31,$B_ORIGINAL,6)*$DE31	+$AD31+$BJ31+2*$S	0.1*$DG31*(0.85+0.15*$NUM/30)	+$AD31+$BJ31+2*$S	0.1*$DI31*(0.5+0.5*$NUM/30)	+$AD31+$BJ31+2*$S	0.5*$DK31*(0.65+0.35*$NUM/30)	+$AD31+$BJ31+2*$S
32	@VLOOKUP($AF32,$B_ORIGINAL,6)*$DE32	+$AD32+$BJ32+2*$S	0.1*$DG32*(0.85+0.15*$NUM/30)	+$AD32+$BJ32+2*$S	0.1*$DI32*(0.5+0.5*$NUM/30)	+$AD32+$BJ32+2*$S	0.5*$DK32*(0.65+0.35*$NUM/30)	+$AD32+$BJ32+2*$S
33	@VLOOKUP($AF33,$B_ORIGINAL,6)*$DE33	+$AD33+$BJ33+2*$S	0.1*$DG33*(0.85+0.15*$NUM/30)	+$AD33+$BJ33+2*$S	0.1*$DI33*(0.5+0.5*$NUM/30)	+$AD33+$BJ33+2*$S	0.5*$DK33*(0.65+0.35*$NUM/30)	+$AD33+$BJ33+2*$S
34	@VLOOKUP($AF34,$B_ORIGINAL,6)*$DE34	+$AD34+$BJ34+2*$S	0.1*$DG34*(0.85+0.15*$NUM/30)	+$AD34+$BJ34+2*$S	0.1*$DI34*(0.5+0.5*$NUM/30)	+$AD34+$BJ34+2*$S	0.5*$DK34*(0.65+0.35*$NUM/30)	+$AD34+$BJ34+2*$S
35	@VLOOKUP($AF35,$B_ORIGINAL,6)*$DE35	+$AD35+$BJ35+2*$S	0.1*$DG35*(0.85+0.15*$NUM/30)	+$AD35+$BJ35+2*$S	0.1*$DI35*(0.5+0.5*$NUM/30)	+$AD35+$BJ35+2*$S	0.5*$DK35*(0.65+0.35*$NUM/30)	+$AD35+$BJ35+2*$S
36	@VLOOKUP($AF36,$B_ORIGINAL,6)*$DE36	+$AD36+$BJ36+2*$S	0.1*$DG36*(0.85+0.15*$NUM/30)	+$AD36+$BJ36+2*$S	0.1*$DI36*(0.5+0.5*$NUM/30)	+$AD36+$BJ36+2*$S	0.5*$DK36*(0.65+0.35*$NUM/30)	+$AD36+$BJ36+2*$S
37	@VLOOKUP($AF37,$B_ORIGINAL,6)*$DE37	+$AD37+$BJ37+2*$S	0.1*$DG37*(0.85+0.15*$NUM/30)	+$AD37+$BJ37+2*$S	0.1*$DI37*(0.5+0.5*$NUM/30)	+$AD37+$BJ37+2*$S	0.5*$DK37*(0.65+0.35*$NUM/30)	+$AD37+$BJ37+2*$S
38	@VLOOKUP($AF38,$B_ORIGINAL,6)*$DE38	+$AD38+$BJ38+2*$S	0.1*$DG38*(0.85+0.15*$NUM/30)	+$AD38+$BJ38+2*$S	0.1*$DI38*(0.5+0.5*$NUM/30)	+$AD38+$BJ38+2*$S	0.5*$DK38*(0.65+0.35*$NUM/30)	+$AD38+$BJ38+2*$S
39	@VLOOKUP($AF39,$B_ORIGINAL,6)*$DE39	+$AD39+$BJ39+2*$S	0.1*$DG39*(0.85+0.15*$NUM/30)	+$AD39+$BJ39+2*$S	0.1*$DI39*(0.5+0.5*$NUM/30)	+$AD39+$BJ39+2*$S	0.5*$DK39*(0.65+0.35*$NUM/30)	+$AD39+$BJ39+2*$S
40	@VLOOKUP($AF40,$B_ORIGINAL,6)*$DE40	+$AD40+$BJ40+$S	0.1*$DG40*(0.85+0.15*$NUM/30)	+$AD40+$BJ40+2*$S	0.1*$DI40*(0.5+0.5*$NUM/30)	+$AD40+$BJ40+2*$S	0.5*$DK40*(0.65+0.35*$NUM/30)	+$AD40+$BJ40+2*$S
41	@VLOOKUP($AF41,$B_ORIGINAL,6)*$DE41	+$AD41+$BJ41+$S	0.1*$DG41*(0.85+0.15*$NUM/30)	+$AD41+$BJ41+2*$S	0.1*$DI41*(0.5+0.5*$NUM/30)	+$AD41+$BJ41+2*$S	0.5*$DK41*(0.65+0.35*$NUM/30)	+$AD41+$BJ41+2*$S
42	@VLOOKUP($AF42,$B_ORIGINAL,6)*$DE42	+$AD42+$BJ42+$S	0.1*$DG42*(0.85+0.15*$NUM/30)	+$AD42+$BJ42+2*$S	0.1*$DI42*(0.5+0.5*$NUM/30)	+$AD42+$BJ42+2*$S	0.5*$DK42*(0.65+0.35*$NUM/30)	+$AD42+$BJ42+2*$S
43	@VLOOKUP($AF43,$B_ORIGINAL,6)*$DE43	+$AD43+$BJ43+$S	0.1*$DG43*(0.85+0.15*$NUM/30)	+$AD43+$BJ43+2*$S	0.1*$DI43*(0.5+0.5*$NUM/30)	+$AD43+$BJ43+2*$S	0.5*$DK43*(0.65+0.35*$NUM/30)	+$AD43+$BJ43+2*$S
44	@VLOOKUP($AF44,$B_ORIGINAL,6)*$DE44	+$S	0.1*$DG44*(0.85+0.15*$NUM/30)	+$S	0.1*$DI44*(0.5+0.5*$NUM/30)	+$S	0.5*$DK44*(0.65+0.35*$NUM/30)	+$S
45	@VLOOKUP($AF45,$B_ORIGINAL,6)*$DE45	+$S	0.1*$DG45*(0.85+0.15*$NUM/30)	+$S	0.1*$DI45*(0.5+0.5*$NUM/30)	+$S	0.5*$DK45*(0.65+0.35*$NUM/30)	+$S
46	@VLOOKUP($AF46,$B_ORIGINAL,6)*$DE46	+$S	0.1*$DG46*(0.85+0.15*$NUM/30)	+$S	0.1*$DI46*(0.5+0.5*$NUM/30)	+$S	0.5*$DK46*(0.65+0.35*$NUM/30)	+$S
47	@VLOOKUP($AF47,$B_ORIGINAL,6)*$DE47	+$S	0.1*$DG47*(0.85+0.15*$NUM/30)	+$S	0.1*$DI47*(0.5+0.5*$NUM/30)	+$S	0.5*$DK47*(0.65+0.35*$NUM/30)	+$S
48	@VLOOKUP($AF48,$B_ORIGINAL,6)*$DE48	+$S	0.1*$DG48*(0.85+0.15*$NUM/30)	+$S	0.1*$DI48*(0.5+0.5*$NUM/30)	+$S	0.5*$DK48*(0.65+0.35*$NUM/30)	+$S
49	@VLOOKUP($AF49,$B_ORIGINAL,6)*$DE49	+$S	0.1*$DG49*(0.85+0.15*$NUM/30)	+$S	0.1*$DI49*(0.5+0.5*$NUM/30)	+$S	0.5*$DK49*(0.65+0.35*$NUM/30)	+$S
50	@VLOOKUP($AF50,$B_ORIGINAL,6)*$DE50	+$S	0.1*$DG50*(0.85+0.15*$NUM/30)	+$S	0.1*$DI50*(0.5+0.5*$NUM/30)	+$S	0.5*$DK50*(0.65+0.35*$NUM/30)	+$S
51	@VLOOKUP($AF51,$B_ORIGINAL,6)*$DE51	+$S	0.1*$DG51*(0.85+0.15*$NUM/30)	+$S	0.1*$DI51*(0.5+0.5*$NUM/30)	+$S	0.5*$DK51*(0.65+0.35*$NUM/30)	+$S
52	@VLOOKUP($AF52,$B_ORIGINAL,6)*$DE52	+$S	0.1*$DG52*(0.85+0.15*$NUM/30)	+$S	0.1*$DI52*(0.5+0.5*$NUM/30)	+$S	0.5*$DK52*(0.65+0.35*$NUM/30)	+$S
53	@VLOOKUP($AF53,$B_ORIGINAL,6)*$DE53	+$S	0.1*$DG53*(0.85+0.15*$NUM/30)	+$S	0.1*$DI53*(0.5+0.5*$NUM/30)	+$S	0.5*$DK53*(0.65+0.35*$NUM/30)	+$S
54	@VLOOKUP($AF54,$B_ORIGINAL,6)*$DE54	+$S	0.1*$DG54*(0.85+0.15*$NUM/30)	+$S	0.1*$DI54*(0.5+0.5*$NUM/30)	+$S	0.5*$DK54*(0.65+0.35*$NUM/30)	+$S
55	@VLOOKUP($AF55,$B_ORIGINAL,6)*$DE55	+$S	0.1*$DG55*(0.85+0.15*$NUM/30)	+$S	0.1*$DI55*(0.5+0.5*$NUM/30)	+$S	0.5*$DK55*(0.65+0.35*$NUM/30)	+$S
56	@VLOOKUP($AF56,$B_ORIGINAL,6)*$DE56	+$S	0.1*$DG56*(0.85+0.15*$NUM/30)	+$S	0.1*$DI56*(0.5+0.5*$NUM/30)	+$S	0.5*$DK56*(0.65+0.35*$NUM/30)	+$S
57	@SUM(DF56..DF12)		@SUM(DH56..DH12)		@SUM(DJ56..DJ12)		@SUM(DL56..DL12)	

A	DN	DO	DP	DQ	DR
1					
2					
3					
4					
5					
6					
7					
8		Blast		Coating	
9					
10					
11					
12	0.5*$DM12*(0.85+0.15*$NUM/30)	2*($AQ12+$BO12+$BF12)	0.033*$DO12*(0.85+0.15*$NUM/30)	2*($AQ12+$BO12+$BF12)	0.033*$DO12*(0.85+0.15*$NUM/30)
13	0.5*$DM13*(0.85+0.15*$NUM/30)	2*($AQ13+$BO13+$BF13)	0.033*$DO13*(0.85+0.15*$NUM/30)	2*($AQ13+$BO13+$BF13)	0.033*$DO13*(0.85+0.15*$NUM/30)
14	0.5*$DM14*(0.85+0.15*$NUM/30)	2*($AQ14+$BO14+$BF14)	0.033*$DO14*(0.85+0.15*$NUM/30)	2*($AQ14+$BO14+$BF14)	0.033*$DO14*(0.85+0.15*$NUM/30)
15	0.5*$DM15*(0.85+0.15*$NUM/30)	2*($AQ15+$BO15+$BF15)	0.033*$DO15*(0.85+0.15*$NUM/30)	2*($AQ15+$BO15+$BF15)	0.033*$DO15*(0.85+0.15*$NUM/30)
16	0.5*$DM16*(0.85+0.15*$NUM/30)	2*($AQ16+$BO16+$BF16)	0.033*$DO16*(0.85+0.15*$NUM/30)	2*($AQ16+$BO16+$BF16)	0.033*$DO16*(0.85+0.15*$NUM/30)
17	0.5*$DM17*(0.85+0.15*$NUM/30)	2*($AQ17+$BO17+$BF17)	0.033*$DO17*(0.85+0.15*$NUM/30)	2*($AQ17+$BO17+$BF17)	0.033*$DO17*(0.85+0.15*$NUM/30)
18	0.5*$DM18*(0.85+0.15*$NUM/30)	2*($AQ18+$BO18+$BF18)	0.033*$DO18*(0.85+0.15*$NUM/30)	2*($AQ18+$BO18+$BF18)	0.033*$DO18*(0.85+0.15*$NUM/30)
19	0.5*$DM19*(0.85+0.15*$NUM/30)	2*($AQ19+$BO19+$BF19)	0.033*$DO19*(0.85+0.15*$NUM/30)	2*($AQ19+$BO19+$BF19)	0.033*$DO19*(0.85+0.15*$NUM/30)
20	0.5*$DM20*(0.85+0.15*$NUM/30)	2*($AQ20+$BO20+$BF20)	0.033*$DO20*(0.85+0.15*$NUM/30)	2*($AQ20+$BO20+$BF20)	0.033*$DO20*(0.85+0.15*$NUM/30)
21	0.5*$DM21*(0.85+0.15*$NUM/30)	2*($AQ21+$BO21+$BF21)	0.033*$DO21*(0.85+0.15*$NUM/30)	2*($AQ21+$BO21+$BF21)	0.033*$DO21*(0.85+0.15*$NUM/30)
22	0.5*$DM22*(0.85+0.15*$NUM/30)	2*($AQ22+$BO22+$BF22)	0.033*$DO22*(0.85+0.15*$NUM/30)	2*($AQ22+$BO22+$BF22)	0.033*$DO22*(0.85+0.15*$NUM/30)
23	0.5*$DM23*(0.85+0.15*$NUM/30)	2*($AQ23+$BO23+$BF23)	0.033*$DO23*(0.85+0.15*$NUM/30)	2*($AQ23+$BO23+$BF23)	0.033*$DO23*(0.85+0.15*$NUM/30)
24	0.5*$DM24*(0.85+0.15*$NUM/30)	2*($AQ24+$BO24+$BF24)	0.033*$DO24*(0.85+0.15*$NUM/30)	2*($AQ24+$BO24+$BF24)	0.033*$DO24*(0.85+0.15*$NUM/30)
25	0.5*$DM25*(0.85+0.15*$NUM/30)	2*($AQ25+$BO25+$BF25)	0.033*$DO25*(0.85+0.15*$NUM/30)	2*($AQ25+$BO25+$BF25)	0.033*$DO25*(0.85+0.15*$NUM/30)
26	0.5*$DM26*(0.85+0.15*$NUM/30)	2*($AQ26+$BO26+$BF26)	0.033*$DO26*(0.85+0.15*$NUM/30)	2*($AQ26+$BO26+$BF26)	0.033*$DO26*(0.85+0.15*$NUM/30)
27	0.5*$DM27*(0.85+0.15*$NUM/30)	2*($AQ27+$BO27+$BF27)	0.033*$DO27*(0.85+0.15*$NUM/30)	2*($AQ27+$BO27+$BF27)	0.033*$DO27*(0.85+0.15*$NUM/30)
28	0.5*$DM28*(0.85+0.15*$NUM/30)	2*($AQ28+$BO28+$BF28)	0.033*$DO28*(0.85+0.15*$NUM/30)	2*($AQ28+$BO28+$BF28)	0.033*$DO28*(0.85+0.15*$NUM/30)
29	0.5*$DM29*(0.85+0.15*$NUM/30)	2*($AQ29+$BO29+$BF29)	0.033*$DO29*(0.85+0.15*$NUM/30)	2*($AQ29+$BO29+$BF29)	0.033*$DO29*(0.85+0.15*$NUM/30)
30	0.5*$DM30*(0.85+0.15*$NUM/30)	2*($AQ30+$BO30+$BF30)	0.033*$DO30*(0.85+0.15*$NUM/30)	2*($AQ30+$BO30+$BF30)	0.033*$DO30*(0.85+0.15*$NUM/30)
31	0.5*$DM31*(0.85+0.15*$NUM/30)	2*($AQ31+$BO31+$BF31)	0.033*$DO31*(0.85+0.15*$NUM/30)	2*($AQ31+$BO31+$BF31)	0.033*$DO31*(0.85+0.15*$NUM/30)
32	0.5*$DM32*(0.85+0.15*$NUM/30)	2*($AQ32+$BO32+$BF32)	0.033*$DO32*(0.85+0.15*$NUM/30)	2*($AQ32+$BO32+$BF32)	0.033*$DO32*(0.85+0.15*$NUM/30)
33	0.5*$DM33*(0.85+0.15*$NUM/30)	2*($AQ33+$BO33+$BF33)	0.033*$DO33*(0.85+0.15*$NUM/30)	2*($AQ33+$BO33+$BF33)	0.033*$DO33*(0.85+0.15*$NUM/30)
34	0.5*$DM34*(0.85+0.15*$NUM/30)	2*($AQ34+$BO34+$BF34)	0.033*$DO34*(0.85+0.15*$NUM/30)	2*($AQ34+$BO34+$BF34)	0.033*$DO34*(0.85+0.15*$NUM/30)
35	0.5*$DM35*(0.85+0.15*$NUM/30)	2*($AQ35+$BO35+$BF35)	0.033*$DO35*(0.85+0.15*$NUM/30)	2*($AQ35+$BO35+$BF35)	0.033*$DO35*(0.85+0.15*$NUM/30)
36	0.5*$DM36*(0.85+0.15*$NUM/30)	2*($AQ36+$BO36+$BF36)	0.033*$DO36*(0.85+0.15*$NUM/30)	2*($AQ36+$BO36+$BF36)	0.033*$DO36*(0.85+0.15*$NUM/30)
37	0.5*$DM37*(0.85+0.15*$NUM/30)	2*($AQ37+$BO37+$BF37)	0.033*$DO37*(0.85+0.15*$NUM/30)	2*($AQ37+$BO37+$BF37)	0.033*$DO37*(0.85+0.15*$NUM/30)
38	0.5*$DM38*(0.85+0.15*$NUM/30)	2*($AQ38+$BO38+$BF38)	0.033*$DO38*(0.85+0.15*$NUM/30)	2*($AQ38+$BO38+$BF38)	0.033*$DO38*(0.85+0.15*$NUM/30)
39	0.5*$DM39*(0.85+0.15*$NUM/30)	2*($AQ39+$BO39+$BF39)	0.033*$DO39*(0.85+0.15*$NUM/30)	2*($AQ39+$BO39+$BF39)	0.033*$DO39*(0.85+0.15*$NUM/30)
40	0.5*$DM40*(0.85+0.15*$NUM/30)	2*($AQ40+$BO40+$BF40)	0.033*$DO40*(0.85+0.15*$NUM/30)	2*($AQ40+$BO40+$BF40)	0.033*$DO40*(0.85+0.15*$NUM/30)
41	0.5*$DM41*(0.85+0.15*$NUM/30)	2*($AQ41+$BO41+$BF41)	0.033*$DO41*(0.85+0.15*$NUM/30)	2*($AQ41+$BO41+$BF41)	0.033*$DO41*(0.85+0.15*$NUM/30)
42	0.5*$DM42*(0.85+0.15*$NUM/30)	2*($AQ42+$BO42+$BF42)	0.033*$DO42*(0.85+0.15*$NUM/30)	2*($AQ42+$BO42+$BF42)	0.033*$DO42*(0.85+0.15*$NUM/30)
43	0.5*$DM43*(0.85+0.15*$NUM/30)	2*($AQ43+$BO43+$BF43)	0.033*$DO43*(0.85+0.15*$NUM/30)	2*($AQ43+$BO43+$BF43)	0.033*$DO43*(0.85+0.15*$NUM/30)
44	0.5*$DM44*(0.85+0.15*$NUM/30)	2*($AQ44+$BO44+$BF44)	0.033*$DO44*(0.85+0.15*$NUM/30)	2*($AQ44+$BO44+$BF44)	0.033*$DO44*(0.85+0.15*$NUM/30)
45	0.5*$DM45*(0.85+0.15*$NUM/30)	2*($AQ45+$BO45+$BF45)	0.033*$DO45*(0.85+0.15*$NUM/30)	2*($AQ45+$BO45+$BF45)	0.033*$DO45*(0.85+0.15*$NUM/30)
46	0.5*$DM46*(0.85+0.15*$NUM/30)	2*($AQ46+$BO46+$BF46)	0.033*$DO46*(0.85+0.15*$NUM/30)	2*($AQ46+$BO46+$BF46)	0.033*$DO46*(0.85+0.15*$NUM/30)
47	0.5*$DM47*(0.85+0.15*$NUM/30)	2*($AQ47+$BO47+$BF47)	0.033*$DO47*(0.85+0.15*$NUM/30)	2*($AQ47+$BO47+$BF47)	0.033*$DO47*(0.85+0.15*$NUM/30)
48	0.5*$DM48*(0.85+0.15*$NUM/30)	2*($AQ48+$BO48+$BF48)	0.033*$DO48*(0.85+0.15*$NUM/30)	2*($AQ48+$BO48+$BF48)	0.033*$DO48*(0.85+0.15*$NUM/30)
49	0.5*$DM49*(0.85+0.15*$NUM/30)	2*($AQ49+$BO49+$BF49)	0.033*$DO49*(0.85+0.15*$NUM/30)	2*($AQ49+$BO49+$BF49)	0.033*$DO49*(0.85+0.15*$NUM/30)
50	0.5*$DM50*(0.85+0.15*$NUM/30)	2*($AQ50+$BO50+$BF50)	0.033*$DO50*(0.85+0.15*$NUM/30)	2*($AQ50+$BO50+$BF50)	0.033*$DO50*(0.85+0.15*$NUM/30)
51	0.5*$DM51*(0.85+0.15*$NUM/30)	2*($AQ51+$BO51+$BF51)	0.033*$DO51*(0.85+0.15*$NUM/30)	2*($AQ51+$BO51+$BF51)	0.033*$DO51*(0.85+0.15*$NUM/30)
52	0.5*$DM52*(0.85+0.15*$NUM/30)	2*($AQ52+$BO52+$BF52)	0.033*$DO52*(0.85+0.15*$NUM/30)	2*($AQ52+$BO52+$BF52)	0.033*$DO52*(0.85+0.15*$NUM/30)
53	0.5*$DM53*(0.85+0.15*$NUM/30)	2*($AQ53+$BO53+$BF53)	0.033*$DO53*(0.85+0.15*$NUM/30)	2*($AQ53+$BO53+$BF53)	0.033*$DO53*(0.85+0.15*$NUM/30)
54	0.5*$DM54*(0.85+0.15*$NUM/30)	2*($AQ54+$BO54+$BF54)	0.033*$DO54*(0.85+0.15*$NUM/30)	2*($AQ54+$BO54+$BF54)	0.033*$DO54*(0.85+0.15*$NUM/30)
55	0.5*$DM55*(0.85+0.15*$NUM/30)	2*($AQ55+$BO55+$BF55)	0.033*$DO55*(0.85+0.15*$NUM/30)	2*($AQ55+$BO55+$BF55)	0.033*$DO55*(0.85+0.15*$NUM/30)
56	0.5*$DM56*(0.85+0.15*$NUM/30)	2*($AQ56+$BO56+$BF56)	0.033*$DO56*(0.85+0.15*$NUM/30)	2*($AQ56+$BO56+$BF56)	0.033*$DO56*(0.85+0.15*$NUM/30)
57	@SUM(DN56..DN12)		@SUM(DP56..DP12)		@SUM(DR56..DR12)

TEXT - Main Spreadsheet

A	DS	DT	DU	DV
1				
2				
3				
4			"IT" -split - used?	
5				
6				$/MHR=
7				
8	Total	Total Support	Total Production	Labor Cost
9	MHRS	MHRS	MHRS	$
10				
11				
12	+$BS12+$BW12+$BZ12+$CC12+$CF12+$CI12+$CK12+$CM12+$CP12+$CT12+$CV12+$CX12+$CZ12+$DB12+$DD12+$DF12+$DH12+$DJ12+$DL12+$DN12+$DP12+$DR12	0.5*$DS12	+$DS12+$DT12	+$RATE*$DU12
13	+$BS13+$BW13+$BZ13+$CC13+$CF13+$CI13+$CK13+$CM13+$CP13+$CT13+$CV13+$CX13+$CZ13+$DB13+$DD13+$DF13+$DH13+$DJ13+$DL13+$DN13+$DP13+$DR13	0.5*$DS13	+$DS13+$DT13	+$RATE*$DU13
14	+$BS14+$BW14+$BZ14+$CC14+$CF14+$CI14+$CK14+$CM14+$CP14+$CT14+$CV14+$CX14+$CZ14+$DB14+$DD14+$DF14+$DH14+$DJ14+$DL14+$DN14+$DP14+$DR14	0.5*$DS14	+$DS14+$DT14	+$RATE*$DU14
15	+$BS15+$BW15+$BZ15+$CC15+$CF15+$CI15+$CK15+$CM15+$CP15+$CT15+$CV15+$CX15+$CZ15+$DB15+$DD15+$DF15+$DH15+$DJ15+$DL15+$DN15+$DP15+$DR15	0.5*$DS15	+$DS15+$DT15	+$RATE*$DU15
16	+$BS16+$BW16+$BZ16+$CC16+$CF16+$CI16+$CK16+$CM16+$CP16+$CT16+$CV16+$CX16+$CZ16+$DB16+$DD16+$DF16+$DH16+$DJ16+$DL16+$DN16+$DP16+$DR16	0.5*$DS16	+$DS16+$DT16	+$RATE*$DU16
17	+$BS17+$BW17+$BZ17+$CC17+$CF17+$CI17+$CK17+$CM17+$CP17+$CT17+$CV17+$CX17+$CZ17+$DB17+$DD17+$DF17+$DH17+$DJ17+$DL17+$DN17+$DP17+$DR17	0.5*$DS17	+$DS17+$DT17	+$RATE*$DU17
18	+$BS18+$BW18+$BZ18+$CC18+$CF18+$CI18+$CK18+$CM18+$CP18+$CT18+$CV18+$CX18+$CZ18+$DB18+$DD18+$DF18+$DH18+$DJ18+$DL18+$DN18+$DP18+$DR18	0.5*$DS18	+$DS18+$DT18	+$RATE*$DU18
19	+$BS19+$BW19+$BZ19+$CC19+$CF19+$CI19+$CK19+$CM19+$CP19+$CT19+$CV19+$CX19+$CZ19+$DB19+$DD19+$DF19+$DH19+$DJ19+$DL19+$DN19+$DP19+$DR19	0.5*$DS19	+$DS19+$DT19	+$RATE*$DU19
20	+$BS20+$BW20+$BZ20+$CC20+$CF20+$CI20+$CK20+$CM20+$CP20+$CT20+$CV20+$CX20+$CZ20+$DB20+$DD20+$DF20+$DH20+$DJ20+$DL20+$DN20+$DP20+$DR20	0.5*$DS20	+$DS20+$DT20	+$RATE*$DU20
21	+$BS21+$BW21+$BZ21+$CC21+$CF21+$CI21+$CK21+$CM21+$CP21+$CT21+$CV21+$CX21+$CZ21+$DB21+$DD21+$DF21+$DH21+$DJ21+$DL21+$DN21+$DP21+$DR21	0.5*$DS21	+$DS21+$DT21	+$RATE*$DU21
22	+$BS22+$BW22+$BZ22+$CC22+$CF22+$CI22+$CK22+$CM22+$CP22+$CT22+$CV22+$CX22+$CZ22+$DB22+$DD22+$DF22+$DH22+$DJ22+$DL22+$DN22+$DP22+$DR22	0.5*$DS22	+$DS22+$DT22	+$RATE*$DU22
23	+$BS23+$BW23+$BZ23+$CC23+$CF23+$CI23+$CK23+$CM23+$CP23+$CT23+$CV23+$CX23+$CZ23+$DB23+$DD23+$DF23+$DH23+$DJ23+$DL23+$DN23+$DP23+$DR23	0.5*$DS23	+$DS23+$DT23	+$RATE*$DU23
24	+$BS24+$BW24+$BZ24+$CC24+$CF24+$CI24+$CK24+$CM24+$CP24+$CT24+$CV24+$CX24+$CZ24+$DB24+$DD24+$DF24+$DH24+$DJ24+$DL24+$DN24+$DP24+$DR24	0.5*$DS24	+$DS24+$DT24	+$RATE*$DU24
25	+$BS25+$BW25+$BZ25+$CC25+$CF25+$CI25+$CK25+$CM25+$CP25+$CT25+$CV25+$CX25+$CZ25+$DB25+$DD25+$DF25+$DH25+$DJ25+$DL25+$DN25+$DP25+$DR25	0.5*$DS25	+$DS25+$DT25	+$RATE*$DU25
26	+$BS26+$BW26+$BZ26+$CC26+$CF26+$CI26+$CK26+$CM26+$CP26+$CT26+$CV26+$CX26+$CZ26+$DB26+$DD26+$DF26+$DH26+$DJ26+$DL26+$DN26+$DP26+$DR26	0.5*$DS26	+$DS26+$DT26	+$RATE*$DU26
27	+$BS27+$BW27+$BZ27+$CC27+$CF27+$CI27+$CK27+$CM27+$CP27+$CT27+$CV27+$CX27+$CZ27+$DB27+$DD27+$DF27+$DH27+$DJ27+$DL27+$DN27+$DP27+$DR27	0.5*$DS27	+$DS27+$DT27	+$RATE*$DU27
28	+$BS28+$BW28+$BZ28+$CC28+$CF28+$CI28+$CK28+$CM28+$CP28+$CT28+$CV28+$CX28+$CZ28+$DB28+$DD28+$DF28+$DH28+$DJ28+$DL28+$DN28+$DP28+$DR28	0.5*$DS28	+$DS28+$DT28	+$RATE*$DU28
29	+$BS29+$BW29+$BZ29+$CC29+$CF29+$CI29+$CK29+$CM29+$CP29+$CT29+$CV29+$CX29+$CZ29+$DB29+$DD29+$DF29+$DH29+$DJ29+$DL29+$DN29+$DP29+$DR29	0.5*$DS29	+$DS29+$DT29	+$RATE*$DU29
30	+$BS30+$BW30+$BZ30+$CC30+$CF30+$CI30+$CK30+$CM30+$CP30+$CT30+$CV30+$CX30+$CZ30+$DB30+$DD30+$DF30+$DH30+$DJ30+$DL30+$DN30+$DP30+$DR30	0.5*$DS30	+$DS30+$DT30	+$RATE*$DU30
31	+$BS31+$BW31+$BZ31+$CC31+$CF31+$CI31+$CK31+$CM31+$CP31+$CT31+$CV31+$CX31+$CZ31+$DB31+$DD31+$DF31+$DH31+$DJ31+$DL31+$DN31+$DP31+$DR31	0.5*$DS31	+$DS31+$DT31	+$RATE*$DU31
32	+$BS32+$BW32+$BZ32+$CC32+$CF32+$CI32+$CK32+$CM32+$CP32+$CT32+$CV32+$CX32+$CZ32+$DB32+$DD32+$DF32+$DH32+$DJ32+$DL32+$DN32+$DP32+$DR32	0.5*$DS32	+$DS32+$DT32	+$RATE*$DU32
33	+$BS33+$BW33+$BZ33+$CC33+$CF33+$CI33+$CK33+$CM33+$CP33+$CT33+$CV33+$CX33+$CZ33+$DB33+$DD33+$DF33+$DH33+$DJ33+$DL33+$DN33+$DP33+$DR33	0.5*$DS33	+$DS33+$DT33	+$RATE*$DU33
34	+$BS34+$BW34+$BZ34+$CC34+$CF34+$CI34+$CK34+$CM34+$CP34+$CT34+$CV34+$CX34+$CZ34+$DB34+$DD34+$DF34+$DH34+$DJ34+$DL34+$DN34+$DP34+$DR34	0.5*$DS34	+$DS34+$DT34	+$RATE*$DU34
35	+$BS35+$BW35+$BZ35+$CC35+$CF35+$CI35+$CK35+$CM35+$CP35+$CT35+$CV35+$CX35+$CZ35+$DB35+$DD35+$DF35+$DH35+$DJ35+$DL35+$DN35+$DP35+$DR35	0.5*$DS35	+$DS35+$DT35	+$RATE*$DU35
36	+$BS36+$BW36+$BZ36+$CC36+$CF36+$CI36+$CK36+$CM36+$CP36+$CT36+$CV36+$CX36+$CZ36+$DB36+$DD36+$DF36+$DH36+$DJ36+$DL36+$DN36+$DP36+$DR36	0.5*$DS36	+$DS36+$DT36	+$RATE*$DU36
37	+$BS37+$BW37+$BZ37+$CC37+$CF37+$CI37+$CK37+$CM37+$CP37+$CT37+$CV37+$CX37+$CZ37+$DB37+$DD37+$DF37+$DH37+$DJ37+$DL37+$DN37+$DP37+$DR37	0.5*$DS37	+$DS37+$DT37	+$RATE*$DU37
38	+$BS38+$BW38+$BZ38+$CC38+$CF38+$CI38+$CK38+$CM38+$CP38+$CT38+$CV38+$CX38+$CZ38+$DB38+$DD38+$DF38+$DH38+$DJ38+$DL38+$DN38+$DP38+$DR38	0.5*$DS38	+$DS38+$DT38	+$RATE*$DU38
39	+$BS39+$BW39+$BZ39+$CC39+$CF39+$CI39+$CK39+$CM39+$CP39+$CT39+$CV39+$CX39+$CZ39+$DB39+$DD39+$DF39+$DH39+$DJ39+$DL39+$DN39+$DP39+$DR39	0.5*$DS39	+$DS39+$DT39	+$RATE*$DU39
40	+$BS40+$BW40+$BZ40+$CC40+$CF40+$CI40+$CK40+$CM40+$CP40+$CT40+$CV40+$CX40+$CZ40+$DB40+$DD40+$DF40+$DH40+$DJ40+$DL40+$DN40+$DP40+$DR40	0.5*$DS40	+$DS40+$DT40	+$RATE*$DU40
41	+$BS41+$BW41+$BZ41+$CC41+$CF41+$CI41+$CK41+$CM41+$CP41+$CT41+$CV41+$CX41+$CZ41+$DB41+$DD41+$DF41+$DH41+$DJ41+$DL41+$DN41+$DP41+$DR41	0.5*$DS41	+$DS41+$DT41	+$RATE*$DU41
42	+$BS42+$BW42+$BZ42+$CC42+$CF42+$CI42+$CK42+$CM42+$CP42+$CT42+$CV42+$CX42+$CZ42+$DB42+$DD42+$DF42+$DH42+$DJ42+$DL42+$DN42+$DP42+$DR42	0.5*$DS42	+$DS42+$DT42	+$RATE*$DU42
43	+$BS43+$BW43+$BZ43+$CC43+$CF43+$CI43+$CK43+$CM43+$CP43+$CT43+$CV43+$CX43+$CZ43+$DB43+$DD43+$DF43+$DH43+$DJ43+$DL43+$DN43+$DP43+$DR43	0.5*$DS43	+$DS43+$DT43	+$RATE*$DU43
44	+$BS44+$BW44+$BZ44+$CC44+$CF44+$CI44+$CK44+$CM44+$CP44+$CT44+$CV44+$CX44+$CZ44+$DB44+$DD44+$DF44+$DH44+$DJ44+$DL44+$DN44+$DP44+$DR44	0.5*$DS44	+$DS44+$DT44	+$RATE*$DU44
45	+$BS45+$BW45+$BZ45+$CC45+$CF45+$CI45+$CK45+$CM45+$CP45+$CT45+$CV45+$CX45+$CZ45+$DB45+$DD45+$DF45+$DH45+$DJ45+$DL45+$DN45+$DP45+$DR45	0.5*$DS45	+$DS45+$DT45	+$RATE*$DU45
46	+$BS46+$BW46+$BZ46+$CC46+$CF46+$CI46+$CK46+$CM46+$CP46+$CT46+$CV46+$CX46+$CZ46+$DB46+$DD46+$DF46+$DH46+$DJ46+$DL46+$DN46+$DP46+$DR46	0.5*$DS46	+$DS46+$DT46	+$RATE*$DU46
47	+$BS47+$BW47+$BZ47+$CC47+$CF47+$CI47+$CK47+$CM47+$CP47+$CT47+$CV47+$CX47+$CZ47+$DB47+$DD47+$DF47+$DH47+$DJ47+$DL47+$DN47+$DP47+$DR47	0.5*$DS47	+$DS47+$DT47	+$RATE*$DU47
48	+$BS48+$BW48+$BZ48+$CC48+$CF48+$CI48+$CK48+$CM48+$CP48+$CT48+$CV48+$CX48+$CZ48+$DB48+$DD48+$DF48+$DH48+$DJ48+$DL48+$DN48+$DP48+$DR48	0.5*$DS48	+$DS48+$DT48	+$RATE*$DU48
49	+$BS49+$BW49+$BZ49+$CC49+$CF49+$CI49+$CK49+$CM49+$CP49+$CT49+$CV49+$CX49+$CZ49+$DB49+$DD49+$DF49+$DH49+$DJ49+$DL49+$DN49+$DP49+$DR49	0.5*$DS49	+$DS49+$DT49	+$RATE*$DU49
50	+$BS50+$BW50+$BZ50+$CC50+$CF50+$CI50+$CK50+$CM50+$CP50+$CT50+$CV50+$CX50+$CZ50+$DB50+$DD50+$DF50+$DH50+$DJ50+$DL50+$DN50+$DP50+$DR50	0.5*$DS50	+$DS50+$DT50	+$RATE*$DU50
51	+$BS51+$BW51+$BZ51+$CC51+$CF51+$CI51+$CK51+$CM51+$CP51+$CT51+$CV51+$CX51+$CZ51+$DB51+$DD51+$DF51+$DH51+$DJ51+$DL51+$DN51+$DP51+$DR51	0.5*$DS51	+$DS51+$DT51	+$RATE*$DU51
52	+$BS52+$BW52+$BZ52+$CC52+$CF52+$CI52+$CK52+$CM52+$CP52+$CT52+$CV52+$CX52+$CZ52+$DB52+$DD52+$DF52+$DH52+$DJ52+$DL52+$DN52+$DP52+$DR52	0.5*$DS52	+$DS52+$DT52	+$RATE*$DU52
53	+$BS53+$BW53+$BZ53+$CC53+$CF53+$CI53+$CK53+$CM53+$CP53+$CT53+$CV53+$CX53+$CZ53+$DB53+$DD53+$DF53+$DH53+$DJ53+$DL53+$DN53+$DP53+$DR53	0.5*$DS53	+$DS53+$DT53	+$RATE*$DU53
54	+$BS54+$BW54+$BZ54+$CC54+$CF54+$CI54+$CK54+$CM54+$CP54+$CT54+$CV54+$CX54+$CZ54+$DB54+$DD54+$DF54+$DH54+$DJ54+$DL54+$DN54+$DP54+$DR54	0.5*$DS54	+$DS54+$DT54	+$RATE*$DU54
55	+$BS55+$BW55+$BZ55+$CC55+$CF55+$CI55+$CK55+$CM55+$CP55+$CT55+$CV55+$CX55+$CZ55+$DB55+$DD55+$DF55+$DH55+$DJ55+$DL55+$DN55+$DP55+$DR55	0.5*$DS55	+$DS55+$DT55	+$RATE*$DU55
56	+$BS56+$BW56+$BZ56+$CC56+$CF56+$CI56+$CK56+$CM56+$CP56+$CT56+$CV56+$CX56+$CZ56+$DB56+$DD56+$DF56+$DH56+$DJ56+$DL56+$DN56+$DP56+$DR56	0.5*$DS56	+$DS56+$DT56	+$RATE*$DU56
57	@SUM(DS56..DS12)	@SUM(DT56..DT12)	@SUM(DU56..DU12)	@SUM(DV56..DV12)

A	DW	DX	DY
1			
2			
3			
4	no		
5			
6	37 5		
7			
8	Plate Cost	Stiffener Area	Frame Area
9	$		
10			
11			
12	@VLOOKUP($AF12,$LOOKUP_HTS_D,1)*$BP12	+$AG12*$AH12+$AI12*$AJ12	+$AS12*$AT12+$AU12*$AV12
13	@VLOOKUP($AF13,$LOOKUP_HTS_D,1)*$BP13	+$AG13*$AH13+$AI13*$AJ13	+$AS13*$AT13+$AU13*$AV13
14	@VLOOKUP($AF14,$LOOKUP_HTS_D,1)*$BP14	+$AG14*$AH14+$AI14*$AJ14	+$AS14*$AT14+$AU14*$AV14
15	@VLOOKUP($AF15,$LOOKUP_HTS_D,1)*$BP15	+$AG15*$AH15+$AI15*$AJ15	+$AS15*$AT15+$AU15*$AV15
16	@VLOOKUP($AF16,$LOOKUP_HTS_D,1)*$BP16	+$AG16*$AH16+$AI16*$AJ16	+$AS16*$AT16+$AU16*$AV16
17	@VLOOKUP($AF17,$LOOKUP_HTS_D,1)*$BP17	+$AG17*$AH17+$AI17*$AJ17	+$AS17*$AT17+$AU17*$AV17
18	@VLOOKUP($AF18,$LOOKUP_HTS_D,1)*$BP18	+$AG18*$AH18+$AI18*$AJ18	+$AS18*$AT18+$AU18*$AV18
19	@VLOOKUP($AF19,$LOOKUP_HTS_D,1)*$BP19	+$AG19*$AH19+$AI19*$AJ19	+$AS19*$AT19+$AU19*$AV19
20	@VLOOKUP($AF20,$LOOKUP_HTS_D,1)*$BP20	+$AG20*$AH20+$AI20*$AJ20	+$AS20*$AT20+$AU20*$AV20
21	@VLOOKUP($AF21,$LOOKUP_HTS_D,1)*$BP21	+$AG21*$AH21+$AI21*$AJ21	+$AS21*$AT21+$AU21*$AV21
22	@VLOOKUP($AF22,$LOOKUP_HTS_D,1)*$BP22	+$AG22*$AH22+$AI22*$AJ22	+$AS22*$AT22+$AU22*$AV22
23	@VLOOKUP($AF23,$LOOKUP_HTS_D,1)*$BP23	+$AG23*$AH23+$AI23*$AJ23	+$AS23*$AT23+$AU23*$AV23
24	@VLOOKUP($AF24,$LOOKUP_HTS_D,1)*$BP24	+$AG24*$AH24+$AI24*$AJ24	+$AS24*$AT24+$AU24*$AV24
25	@VLOOKUP($AF25,$LOOKUP_HTS_D,1)*$BP25	+$AG25*$AH25+$AI25*$AJ25	+$AS25*$AT25+$AU25*$AV25
26	@VLOOKUP($AF26,$LOOKUP_HTS_D,1)*$BP26	+$AG26*$AH26+$AI26*$AJ26	+$AS26*$AT26+$AU26*$AV26
27	@VLOOKUP($AF27,$LOOKUP_HTS_D,1)*$BP27	+$AG27*$AH27+$AI27*$AJ27	+$AS27*$AT27+$AU27*$AV27
28	@VLOOKUP($AF28,$LOOKUP_HTS_D,1)*$BP28	+$AG28*$AH28+$AI28*$AJ28	+$AS28*$AT28+$AU28*$AV28
29	@VLOOKUP($AF29,$LOOKUP_HTS_D,1)*$BP29	+$AG29*$AH29+$AI29*$AJ29	+$AS29*$AT29+$AU29*$AV29
30	@VLOOKUP($AF30,$LOOKUP_HTS_D,1)*$BP30	+$AG30*$AH30+$AI30*$AJ30	+$AS30*$AT30+$AU30*$AV30
31	@VLOOKUP($AF31,$LOOKUP_HTS_D,1)*$BP31	+$AG31*$AH31+$AI31*$AJ31	+$AS31*$AT31+$AU31*$AV31
32	@VLOOKUP($AF32,$LOOKUP_HTS_D,1)*$BP32	+$AG32*$AH32+$AI32*$AJ32	+$AS32*$AT32+$AU32*$AV32
33	@VLOOKUP($AF33,$LOOKUP_HTS_D,1)*$BP33	+$AG33*$AH33+$AI33*$AJ33	+$AS33*$AT33+$AU33*$AV33
34	@VLOOKUP($AF34,$LOOKUP_HTS_D,1)*$BP34	+$AG34*$AH34+$AI34*$AJ34	+$AS34*$AT34+$AU34*$AV34
35	@VLOOKUP($AF35,$LOOKUP_HTS_D,1)*$BP35	+$AG35*$AH35+$AI35*$AJ35	+$AS35*$AT35+$AU35*$AV35
36	@VLOOKUP($AF36,$LOOKUP_HTS_D,1)*$BP36	+$AG36*$AH36+$AI36*$AJ36	+$AS36*$AT36+$AU36*$AV36
37	@VLOOKUP($AF37,$LOOKUP_HTS_D,1)*$BP37	+$AG37*$AH37+$AI37*$AJ37	+$AS37*$AT37+$AU37*$AV37
38	@VLOOKUP($AF38,$LOOKUP_HTS_D,1)*$BP38	+$AG38*$AH38+$AI38*$AJ38	+$AS38*$AT38+$AU38*$AV38
39	@VLOOKUP($AF39,$LOOKUP_HTS_D,1)*$BP39	+$AG39*$AH39+$AI39*$AJ39	+$AS39*$AT39+$AU39*$AV39
40	@VLOOKUP($AF40,$LOOKUP_HTS_D,1)*$BP40	+$AG40*$AH40+$AI40*$AJ40	+$AS40*$AT40+$AU40*$AV40
41	@VLOOKUP($AF41,$LOOKUP_HTS_D,1)*$BP41	+$AG41*$AH41+$AI41*$AJ41	+$AS41*$AT41+$AU41*$AV41
42	@VLOOKUP($AF42,$LOOKUP_HTS_D,1)*$BP42	+$AG42*$AH42+$AI42*$AJ42	+$AS42*$AT42+$AU42*$AV42
43	@VLOOKUP($AF43,$LOOKUP_HTS_D,1)*$BP43	+$AG43*$AH43+$AI43*$AJ43	+$AS43*$AT43+$AU43*$AV43
44	@VLOOKUP($AF44,$LOOKUP_HTS_D,1)*$BP44	+$AG44*$AH44+$AI44*$AJ44	+$AS44*$AT44+$AU44*$AV44
45	@VLOOKUP($AF45,$LOOKUP_HTS_D,1)*$BP45	+$AG45*$AH45+$AI45*$AJ45	+$AS45*$AT45+$AU45*$AV45
46	@VLOOKUP($AF46,$LOOKUP_HTS_D,1)*$BP46	+$AG46*$AH46+$AI46*$AJ46	+$AS46*$AT46+$AU46*$AV46
47	@VLOOKUP($AF47,$LOOKUP_HTS_D,1)*$BP47	+$AG47*$AH47+$AI47*$AJ47	+$AS47*$AT47+$AU47*$AV47
48	@VLOOKUP($AF48,$LOOKUP_HTS_D,1)*$BP48	+$AG48*$AH48+$AI48*$AJ48	+$AS48*$AT48+$AU48*$AV48
49	@VLOOKUP($AF49,$LOOKUP_HTS_D,1)*$BP49	+$AG49*$AH49+$AI49*$AJ49	+$AS49*$AT49+$AU49*$AV49
50	@VLOOKUP($AF50,$LOOKUP_HTS_D,1)*$BP50	+$AG50*$AH50+$AI50*$AJ50	+$AS50*$AT50+$AU50*$AV50
51	@VLOOKUP($AF51,$LOOKUP_HTS_D,1)*$BP51	+$AG51*$AH51+$AI51*$AJ51	+$AS51*$AT51+$AU51*$AV51
52	@VLOOKUP($AF52,$LOOKUP_HTS_D,1)*$BP52	+$AG52*$AH52+$AI52*$AJ52	+$AS52*$AT52+$AU52*$AV52
53	@VLOOKUP($AF53,$LOOKUP_HTS_D,1)*$BP53	+$AG53*$AH53+$AI53*$AJ53	+$AS53*$AT53+$AU53*$AV53
54	@VLOOKUP($AF54,$LOOKUP_HTS_D,1)*$BP54	+$AG54*$AH54+$AI54*$AJ54	+$AS54*$AT54+$AU54*$AV54
55	@VLOOKUP($AF55,$LOOKUP_HTS_D,1)*$BP55	+$AG55*$AH55+$AI55*$AJ55	+$AS55*$AT55+$AU55*$AV55
56	@VLOOKUP($AF56,$LOOKUP_HTS_D,1)*$BP56	+$AG56*$AH56+$AI56*$AJ56	+$AS56*$AT56+$AU56*$AV56
57	@SUM(DW56..DW12)		

A	DZ
1	
2	
3	
4	
5	
6	
7	
8	Stiffener Cost
9	
10	
11	
12	@IF(DW4="YES",$A*$S*0.283*12*($DX12)/2*(@TANH((2/1.25*$DX12)^3/40-0.375)*0.375+0.6+(2/1.25*$DX12)*0.01),$A*$S*0.283*12*($DX12)*(@TANH(($DX12)^3/40-0.375)*0.375+0.6+$DX12*0.01)+2*0.5*$AD12*$RATE)
13	@IF(DW4="YES",$A*$S*0.283*12*($DX13)/2*(@TANH((2/1.25*$DX13)^3/40-0.375)*0.375+0.6+(2/1.25*$DX13)*0.01),$A*$S*0.283*12*($DX13)*(@TANH(($DX13)^3/40-0.375)*0.375+0.6+$DX13*0.01)+2*0.5*$AD13*$RATE)
14	@IF(DW4="YES",$A*$S*0.283*12*($DX14)/2*(@TANH((2/1.25*$DX14)^3/40-0.375)*0.375+0.6+(2/1.25*$DX14)*0.01),$A*$S*0.283*12*($DX14)*(@TANH(($DX14)^3/40-0.375)*0.375+0.6+$DX14*0.01)+2*0.5*$AD14*$RATE)
15	@IF(DW4="YES",$A*$S*0.283*12*($DX15)/2*(@TANH((2/1.25*$DX15)^3/40-0.375)*0.375+0.6+(2/1.25*$DX15)*0.01),$A*$S*0.283*12*($DX15)*(@TANH(($DX15)^3/40-0.375)*0.375+0.6+$DX15*0.01)+2*0.5*$AD15*$RATE)
16	@IF(DW4="YES",$A*$S*0.283*12*($DX16)/2*(@TANH((2/1.25*$DX16)^3/40-0.375)*0.375+0.6+(2/1.25*$DX16)*0.01),$A*$S*0.283*12*($DX16)*(@TANH(($DX16)^3/40-0.375)*0.375+0.6+$DX16*0.01)+2*0.5*$AD16*$RATE)
17	@IF(DW4="YES",$A*$S*0.283*12*($DX17)/2*(@TANH((2/1.25*$DX17)^3/40-0.375)*0.375+0.6+(2/1.25*$DX17)*0.01),$A*$S*0.283*12*($DX17)*(@TANH(($DX17)^3/40-0.375)*0.375+0.6+$DX17*0.01)+2*0.5*$AD17*$RATE)
18	@IF(DW4="YES",$A*$S*0.283*12*($DX18)/2*(@TANH((2/1.25*$DX18)^3/40-0.375)*0.375+0.6+(2/1.25*$DX18)*0.01),$A*$S*0.283*12*($DX18)*(@TANH(($DX18)^3/40-0.375)*0.375+0.6+$DX18*0.01)+2*0.5*$AD18*$RATE)
19	@IF(DW4="YES",$A*$S*0.283*12*($DX19)/2*(@TANH((2/1.25*$DX19)^3/40-0.375)*0.375+0.6+(2/1.25*$DX19)*0.01),$A*$S*0.283*12*($DX19)*(@TANH(($DX19)^3/40-0.375)*0.375+0.6+$DX19*0.01)+2*0.5*$AD19*$RATE)
20	@IF(DW4="YES",$A*$S*0.283*12*($DX20)/2*(@TANH((2/1.25*$DX20)^3/40-0.375)*0.375+0.6+(2/1.25*$DX20)*0.01),$A*$S*0.283*12*($DX20)*(@TANH(($DX20)^3/40-0.375)*0.375+0.6+$DX20*0.01)+2*0.5*$AD20*$RATE)
21	@IF(DW4="YES",$A*$S*0.283*12*($DX21)/2*(@TANH((2/1.25*$DX21)^3/40-0.375)*0.375+0.6+(2/1.25*$DX21)*0.01),$A*$S*0.283*12*($DX21)*(@TANH(($DX21)^3/40-0.375)*0.375+0.6+$DX21*0.01)+2*0.5*$AD21*$RATE)
22	@IF(DW4="YES",$A*$S*0.283*12*($DX22)/2*(@TANH((2/1.25*$DX22)^3/40-0.375)*0.375+0.6+(2/1.25*$DX22)*0.01),$A*$S*0.283*12*($DX22)*(@TANH(($DX22)^3/40-0.375)*0.375+0.6+$DX22*0.01)+2*0.5*$AD22*$RATE)
23	@IF(DW4="YES",$A*$S*0.283*12*($DX23)/2*(@TANH((2/1.25*$DX23)^3/40-0.375)*0.375+0.6+(2/1.25*$DX23)*0.01),$A*$S*0.283*12*($DX23)*(@TANH(($DX23)^3/40-0.375)*0.375+0.6+$DX23*0.01)+2*0.5*$AD23*$RATE)
24	@IF(DW4="YES",$A*$S*0.283*12*($DX24)/2*(@TANH((2/1.25*$DX24)^3/40-0.375)*0.375+0.6+(2/1.25*$DX24)*0.01),$A*$S*0.283*12*($DX24)*(@TANH(($DX24)^3/40-0.375)*0.375+0.6+$DX24*0.01)+2*0.5*$AD24*$RATE)
25	@IF(DW4="YES",$A*$S*0.283*12*($DX25)/2*(@TANH((2/1.25*$DX25)^3/40-0.375)*0.375+0.6+(2/1.25*$DX25)*0.01),$A*$S*0.283*12*($DX25)*(@TANH(($DX25)^3/40-0.375)*0.375+0.6+$DX25*0.01)+2*0.5*$AD25*$RATE)
26	@IF(DW4="YES",$A*$S*0.283*12*($DX26)/2*(@TANH((2/1.25*$DX26)^3/40-0.375)*0.375+0.6+(2/1.25*$DX26)*0.01),$A*$S*0.283*12*($DX26)*(@TANH(($DX26)^3/40-0.375)*0.375+0.6+$DX26*0.01)+2*0.5*$AD26*$RATE)
27	@IF(DW4="YES",$A*$S*0.283*12*($DX27)/2*(@TANH((2/1.25*$DX27)^3/40-0.375)*0.375+0.6+(2/1.25*$DX27)*0.01),$A*$S*0.283*12*($DX27)*(@TANH(($DX27)^3/40-0.375)*0.375+0.6+$DX27*0.01)+2*0.5*$AD27*$RATE)
28	@IF(DW4="YES",$A*$S*0.283*12*($DX28)/2*(@TANH((2/1.25*$DX28)^3/40-0.375)*0.375+0.6+(2/1.25*$DX28)*0.01),$A*$S*0.283*12*($DX28)*(@TANH(($DX28)^3/40-0.375)*0.375+0.6+$DX28*0.01)+2*0.5*$AD28*$RATE)
29	@IF(DW4="YES",$A*$S*0.283*12*($DX29)/2*(@TANH((2/1.25*$DX29)^3/40-0.375)*0.375+0.6+(2/1.25*$DX29)*0.01),$A*$S*0.283*12*($DX29)*(@TANH(($DX29)^3/40-0.375)*0.375+0.6+$DX29*0.01)+2*0.5*$AD29*$RATE)
30	@IF(DW4="YES",$A*$S*0.283*12*($DX30)/2*(@TANH((2/1.25*$DX30)^3/40-0.375)*0.375+0.6+(2/1.25*$DX30)*0.01),$A*$S*0.283*12*($DX30)*(@TANH(($DX30)^3/40-0.375)*0.375+0.6+$DX30*0.01)+2*0.5*$AD30*$RATE)
31	@IF(DW4="YES",$A*$S*0.283*12*($DX31)/2*(@TANH((2/1.25*$DX31)^3/40-0.375)*0.375+0.6+(2/1.25*$DX31)*0.01),$A*$S*0.283*12*($DX31)*(@TANH(($DX31)^3/40-0.375)*0.375+0.6+$DX31*0.01)+2*0.5*$AD31*$RATE)
32	@IF(DW4="YES",$A*$S*0.283*12*($DX32)/2*(@TANH((2/1.25*$DX32)^3/40-0.375)*0.375+0.6+(2/1.25*$DX32)*0.01),$A*$S*0.283*12*($DX32)*(@TANH(($DX32)^3/40-0.375)*0.375+0.6+$DX32*0.01)+2*0.5*$AD32*$RATE)
33	@IF(DW4="YES",$A*$S*0.283*12*($DX33)/2*(@TANH((2/1.25*$DX33)^3/40-0.375)*0.375+0.6+(2/1.25*$DX33)*0.01),$A*$S*0.283*12*($DX33)*(@TANH(($DX33)^3/40-0.375)*0.375+0.6+$DX33*0.01)+2*0.5*$AD33*$RATE)
34	@IF(DW4="YES",$A*$S*0.283*12*($DX34)/2*(@TANH((2/1.25*$DX34)^3/40-0.375)*0.375+0.6+(2/1.25*$DX34)*0.01),$A*$S*0.283*12*($DX34)*(@TANH(($DX34)^3/40-0.375)*0.375+0.6+$DX34*0.01)+2*0.5*$AD34*$RATE)
35	@IF(DW4="YES",$A*$S*0.283*12*($DX35)/2*(@TANH((2/1.25*$DX35)^3/40-0.375)*0.375+0.6+(2/1.25*$DX35)*0.01),$A*$S*0.283*12*($DX35)*(@TANH(($DX35)^3/40-0.375)*0.375+0.6+$DX35*0.01)+2*0.5*$AD35*$RATE)
36	@IF(DW4="YES",$A*$S*0.283*12*($DX36)/2*(@TANH((2/1.25*$DX36)^3/40-0.375)*0.375+0.6+(2/1.25*$DX36)*0.01),$A*$S*0.283*12*($DX36)*(@TANH(($DX36)^3/40-0.375)*0.375+0.6+$DX36*0.01)+2*0.5*$AD36*$RATE)
37	@IF(DW4="YES",$A*$S*0.283*12*($DX37)/2*(@TANH((2/1.25*$DX37)^3/40-0.375)*0.375+0.6+(2/1.25*$DX37)*0.01),$A*$S*0.283*12*($DX37)*(@TANH(($DX37)^3/40-0.375)*0.375+0.6+$DX37*0.01)+2*0.5*$AD37*$RATE)
38	@IF(DW4="YES",$A*$S*0.283*12*($DX38)/2*(@TANH((2/1.25*$DX38)^3/40-0.375)*0.375+0.6+(2/1.25*$DX38)*0.01),$A*$S*0.283*12*($DX38)*(@TANH(($DX38)^3/40-0.375)*0.375+0.6+$DX38*0.01)+2*0.5*$AD38*$RATE)
39	@IF(DW4="YES",$A*$S*0.283*12*($DX39)/2*(@TANH((2/1.25*$DX39)^3/40-0.375)*0.375+0.6+(2/1.25*$DX39)*0.01),$A*$S*0.283*12*($DX39)*(@TANH(($DX39)^3/40-0.375)*0.375+0.6+$DX39*0.01)+2*0.5*$AD39*$RATE)
40	@IF(DW4="YES",$A*$S*0.283*12*($DX40)/2*(@TANH((2/1.25*$DX40)^3/40-0.375)*0.375+0.6+(2/1.25*$DX40)*0.01),$A*$S*0.283*12*($DX40)*(@TANH(($DX40)^3/40-0.375)*0.375+0.6+$DX40*0.01)+2*0.5*$AD40*$RATE)
41	@IF(DW4="YES",$A*$S*0.283*12*($DX41)/2*(@TANH((2/1.25*$DX41)^3/40-0.375)*0.375+0.6+(2/1.25*$DX41)*0.01),$A*$S*0.283*12*($DX41)*(@TANH(($DX41)^3/40-0.375)*0.375+0.6+$DX41*0.01)+2*0.5*$AD41*$RATE)
42	@IF(DW4="YES",$A*$S*0.283*12*($DX42)/2*(@TANH((2/1.25*$DX42)^3/40-0.375)*0.375+0.6+(2/1.25*$DX42)*0.01),$A*$S*0.283*12*($DX42)*(@TANH(($DX42)^3/40-0.375)*0.375+0.6+$DX42*0.01)+2*0.5*$AD42*$RATE)
43	@IF(DW4="YES",$A*$S*0.283*12*($DX43)/2*(@TANH((2/1.25*$DX43)^3/40-0.375)*0.375+0.6+(2/1.25*$DX43)*0.01),$A*$S*0.283*12*($DX43)*(@TANH(($DX43)^3/40-0.375)*0.375+0.6+$DX43*0.01)+2*0.5*$AD43*$RATE)
44	@IF(DW4="YES",$A*$S*0.283*12*($DX44)/2*(@TANH((2/1.25*$DX44)^3/40-0.375)*0.375+0.6+(2/1.25*$DX44)*0.01),$A*$S*0.283*12*($DX44)*(@TANH(($DX44)^3/40-0.375)*0.375+0.6+$DX44*0.01)+2*0.5*$AD44*$RATE)
45	@IF(DW4="YES",$A*$S*0.283*12*($DX45)/2*(@TANH((2/1.25*$DX45)^3/40-0.375)*0.375+0.6+(2/1.25*$DX45)*0.01),$A*$S*0.283*12*($DX45)*(@TANH(($DX45)^3/40-0.375)*0.375+0.6+$DX45*0.01)+2*0.5*$AD45*$RATE)
46	@IF(DW4="YES",$A*$S*0.283*12*($DX46)/2*(@TANH((2/1.25*$DX46)^3/40-0.375)*0.375+0.6+(2/1.25*$DX46)*0.01),$A*$S*0.283*12*($DX46)*(@TANH(($DX46)^3/40-0.375)*0.375+0.6+$DX46*0.01)+2*0.5*$AD46*$RATE)
47	@IF(DW4="YES",$A*$S*0.283*12*($DX47)/2*(@TANH((2/1.25*$DX47)^3/40-0.375)*0.375+0.6+(2/1.25*$DX47)*0.01),$A*$S*0.283*12*($DX47)*(@TANH(($DX47)^3/40-0.375)*0.375+0.6+$DX47*0.01)+2*0.5*$AD47*$RATE)
48	@IF(DW4="YES",$A*$S*0.283*12*($DX48)/2*(@TANH((2/1.25*$DX48)^3/40-0.375)*0.375+0.6+(2/1.25*$DX48)*0.01),$A*$S*0.283*12*($DX48)*(@TANH(($DX48)^3/40-0.375)*0.375+0.6+$DX48*0.01)+2*0.5*$AD48*$RATE)
49	@IF(DW4="YES",$A*$S*0.283*12*($DX49)/2*(@TANH((2/1.25*$DX49)^3/40-0.375)*0.375+0.6+(2/1.25*$DX49)*0.01),$A*$S*0.283*12*($DX49)*(@TANH(($DX49)^3/40-0.375)*0.375+0.6+$DX49*0.01)+2*0.5*$AD49*$RATE)
50	@IF(DW4="YES",$A*$S*0.283*12*($DX50)/2*(@TANH((2/1.25*$DX50)^3/40-0.375)*0.375+0.6+(2/1.25*$DX50)*0.01),$A*$S*0.283*12*($DX50)*(@TANH(($DX50)^3/40-0.375)*0.375+0.6+$DX50*0.01)+2*0.5*$AD50*$RATE)
51	@IF(DW4="YES",$A*$S*0.283*12*($DX51)/2*(@TANH((2/1.25*$DX51)^3/40-0.375)*0.375+0.6+(2/1.25*$DX51)*0.01),$A*$S*0.283*12*($DX51)*(@TANH(($DX51)^3/40-0.375)*0.375+0.6+$DX51*0.01)+2*0.5*$AD51*$RATE)
52	@IF(DW4="YES",$A*$S*0.283*12*($DX52)/2*(@TANH((2/1.25*$DX52)^3/40-0.375)*0.375+0.6+(2/1.25*$DX52)*0.01),$A*$S*0.283*12*($DX52)*(@TANH(($DX52)^3/40-0.375)*0.375+0.6+$DX52*0.01)+2*0.5*$AD52*$RATE)
53	@IF(DW4="YES",$A*$S*0.283*12*($DX53)/2*(@TANH((2/1.25*$DX53)^3/40-0.375)*0.375+0.6+(2/1.25*$DX53)*0.01),$A*$S*0.283*12*($DX53)*(@TANH(($DX53)^3/40-0.375)*0.375+0.6+$DX53*0.01)+2*0.5*$AD53*$RATE)
54	@IF(DW4="YES",$A*$S*0.283*12*($DX54)/2*(@TANH((2/1.25*$DX54)^3/40-0.375)*0.375+0.6+(2/1.25*$DX54)*0.01),$A*$S*0.283*12*($DX54)*(@TANH(($DX54)^3/40-0.375)*0.375+0.6+$DX54*0.01)+2*0.5*$AD54*$RATE)
55	@IF(DW4="YES",$A*$S*0.283*12*($DX55)/2*(@TANH((2/1.25*$DX55)^3/40-0.375)*0.375+0.6+(2/1.25*$DX55)*0.01),$A*$S*0.283*12*($DX55)*(@TANH(($DX55)^3/40-0.375)*0.375+0.6+$DX55*0.01)+2*0.5*$AD55*$RATE)
56	@IF(DW4="YES",$A*$S*0.283*12*($DX56)/2*(@TANH((2/1.25*$DX56)^3/40-0.375)*0.375+0.6+(2/1.25*$DX56)*0.01),$A*$S*0.283*12*($DX56)*(@TANH(($DX56)^3/40-0.375)*0.375+0.6+$DX56*0.01)+2*0.5*$AD56*$RATE)
57	@SUM(DZ56..DZ12)

A	EA	EB	EC
1			
2			
3			
4			
5			
6			
7			
8	Frame Cost		
9		Matl Cost	Total Cost
10		$	$
11			
12	@IF(DW4="YES",$A*$S*0.283*12*($DY12)/2*(@TANH((2/1.25*$DY12)^3/40-0.375)*0.375+0.6+(2/1.25*$DY12)*0.01),$A*$S*0.283*12*($DY12)*(@TANH(($DY12)^3/40-0.375)*0.375+0.6+$DY12*0.01)+2*0.5*$S*$RATE)	+DW12+DZ12+EA12	+$DV12+$EB12
13	@IF(DW4="YES",$A*$S*0.283*12*($DY13)/2*(@TANH((2/1.25*$DY13)^3/40-0.375)*0.375+0.6+(2/1.25*$DY13)*0.01),$A*$S*0.283*12*($DY13)*(@TANH(($DY13)^3/40-0.375)*0.375+0.6+$DY13*0.01)+2*0.5*$S*$RATE)	+DW13+DZ13+EA13	+$DV13+$EB13
14	@IF(DW4="YES",$A*$S*0.283*12*($DY14)/2*(@TANH((2/1.25*$DY14)^3/40-0.375)*0.375+0.6+(2/1.25*$DY14)*0.01),$A*$S*0.283*12*($DY14)*(@TANH(($DY14)^3/40-0.375)*0.375+0.6+$DY14*0.01)+2*0.5*$S*$RATE)	+DW14+DZ14+EA14	+$DV14+$EB14
15	@IF(DW4="YES",$A*$S*0.283*12*($DY15)/2*(@TANH((2/1.25*$DY15)^3/40-0.375)*0.375+0.6+(2/1.25*$DY15)*0.01),$A*$S*0.283*12*($DY15)*(@TANH(($DY15)^3/40-0.375)*0.375+0.6+$DY15*0.01)+2*0.5*$S*$RATE)	+DW15+DZ15+EA15	+$DV15+$EB15
16	@IF(DW4="YES",$A*$S*0.283*12*($DY16)/2*(@TANH((2/1.25*$DY16)^3/40-0.375)*0.375+0.6+(2/1.25*$DY16)*0.01),$A*$S*0.283*12*($DY16)*(@TANH(($DY16)^3/40-0.375)*0.375+0.6+$DY16*0.01)+2*0.5*$S*$RATE)	+DW16+DZ16+EA16	+$DV16+$EB16
17	@IF(DW4="YES",$A*$S*0.283*12*($DY17)/2*(@TANH((2/1.25*$DY17)^3/40-0.375)*0.375+0.6+(2/1.25*$DY17)*0.01),$A*$S*0.283*12*($DY17)*(@TANH(($DY17)^3/40-0.375)*0.375+0.6+$DY17*0.01)+2*0.5*$S*$RATE)	+DW17+DZ17+EA17	+$DV17+$EB17
18	@IF(DW4="YES",$A*$S*0.283*12*($DY18)/2*(@TANH((2/1.25*$DY18)^3/40-0.375)*0.375+0.6+(2/1.25*$DY18)*0.01),$A*$S*0.283*12*($DY18)*(@TANH(($DY18)^3/40-0.375)*0.375+0.6+$DY18*0.01)+2*0.5*$S*$RATE)	+DW18+DZ18+EA18	+$DV18+$EB18
19	@IF(DW4="YES",$A*$S*0.283*12*($DY19)/2*(@TANH((2/1.25*$DY19)^3/40-0.375)*0.375+0.6+(2/1.25*$DY19)*0.01),$A*$S*0.283*12*($DY19)*(@TANH(($DY19)^3/40-0.375)*0.375+0.6+$DY19*0.01)+2*0.5*$S*$RATE)	+DW19+DZ19+EA19	+$DV19+$EB19
20	@IF(DW4="YES",$A*$S*0.283*12*($DY20)/2*(@TANH((2/1.25*$DY20)^3/40-0.375)*0.375+0.6+(2/1.25*$DY20)*0.01),$A*$S*0.283*12*($DY20)*(@TANH(($DY20)^3/40-0.375)*0.375+0.6+$DY20*0.01)+2*0.5*$S*$RATE)	+DW20+DZ20+EA20	+$DV20+$EB20
21	@IF(DW4="YES",$A*$S*0.283*12*($DY21)/2*(@TANH((2/1.25*$DY21)^3/40-0.375)*0.375+0.6+(2/1.25*$DY21)*0.01),$A*$S*0.283*12*($DY21)*(@TANH(($DY21)^3/40-0.375)*0.375+0.6+$DY21*0.01)+2*0.5*$S*$RATE)	+DW21+DZ21+EA21	+$DV21+$EB21
22	@IF(DW4="YES",$A*$S*0.283*12*($DY22)/2*(@TANH((2/1.25*$DY22)^3/40-0.375)*0.375+0.6+(2/1.25*$DY22)*0.01),$A*$S*0.283*12*($DY22)*(@TANH(($DY22)^3/40-0.375)*0.375+0.6+$DY22*0.01)+2*0.5*$S*$RATE)	+DW22+DZ22+EA22	+$DV22+$EB22
23	@IF(DW4="YES",$A*$S*0.283*12*($DY23)/2*(@TANH((2/1.25*$DY23)^3/40-0.375)*0.375+0.6+(2/1.25*$DY23)*0.01),$A*$S*0.283*12*($DY23)*(@TANH(($DY23)^3/40-0.375)*0.375+0.6+$DY23*0.01)+2*0.5*$S*$RATE)	+DW23+DZ23+EA23	+$DV23+$EB23
24	@IF(DW4="YES",$A*$S*0.283*12*($DY24)/2*(@TANH((2/1.25*$DY24)^3/40-0.375)*0.375+0.6+(2/1.25*$DY24)*0.01),$A*$S*0.283*12*($DY24)*(@TANH(($DY24)^3/40-0.375)*0.375+0.6+$DY24*0.01)+2*0.5*$S*$RATE)	+DW24+DZ24+EA24	+$DV24+$EB24
25	@IF(DW4="YES",$A*$S*0.283*12*($DY25)/2*(@TANH((2/1.25*$DY25)^3/40-0.375)*0.375+0.6+(2/1.25*$DY25)*0.01),$A*$S*0.283*12*($DY25)*(@TANH(($DY25)^3/40-0.375)*0.375+0.6+$DY25*0.01)+2*0.5*$S*$RATE)	+DW25+DZ25+EA25	+$DV25+$EB25
26	@IF(DW4="YES",$A*$S*0.283*12*($DY26)/2*(@TANH((2/1.25*$DY26)^3/40-0.375)*0.375+0.6+(2/1.25*$DY26)*0.01),$A*$S*0.283*12*($DY26)*(@TANH(($DY26)^3/40-0.375)*0.375+0.6+$DY26*0.01)+2*0.5*$S*$RATE)	+DW26+DZ26+EA26	+$DV26+$EB26
27	@IF(DW4="YES",$A*$S*0.283*12*($DY27)/2*(@TANH((2/1.25*$DY27)^3/40-0.375)*0.375+0.6+(2/1.25*$DY27)*0.01),$A*$S*0.283*12*($DY27)*(@TANH(($DY27)^3/40-0.375)*0.375+0.6+$DY27*0.01)+2*0.5*$S*$RATE)	+DW27+DZ27+EA27	+$DV27+$EB27
28	@IF(DW4="YES",$A*$S*0.283*12*($DY28)/2*(@TANH((2/1.25*$DY28)^3/40-0.375)*0.375+0.6+(2/1.25*$DY28)*0.01),$A*$S*0.283*12*($DY28)*(@TANH(($DY28)^3/40-0.375)*0.375+0.6+$DY28*0.01)+2*0.5*$S*$RATE)	+DW28+DZ28+EA28	+$DV28+$EB28
29	@IF(DW4="YES",$A*$S*0.283*12*($DY29)/2*(@TANH((2/1.25*$DY29)^3/40-0.375)*0.375+0.6+(2/1.25*$DY29)*0.01),$A*$S*0.283*12*($DY29)*(@TANH(($DY29)^3/40-0.375)*0.375+0.6+$DY29*0.01)+2*0.5*$S*$RATE)	+DW29+DZ29+EA29	+$DV29+$EB29
30	@IF(DW4="YES",$A*$S*0.283*12*($DY30)/2*(@TANH((2/1.25*$DY30)^3/40-0.375)*0.375+0.6+(2/1.25*$DY30)*0.01),$A*$S*0.283*12*($DY30)*(@TANH(($DY30)^3/40-0.375)*0.375+0.6+$DY30*0.01)+2*0.5*$S*$RATE)	+DW30+DZ30+EA30	+$DV30+$EB30
31	@IF(DW4="YES",$A*$S*0.283*12*($DY31)/2*(@TANH((2/1.25*$DY31)^3/40-0.375)*0.375+0.6+(2/1.25*$DY31)*0.01),$A*$S*0.283*12*($DY31)*(@TANH(($DY31)^3/40-0.375)*0.375+0.6+$DY31*0.01)+2*0.5*$S*$RATE)	+DW31+DZ31+EA31	+$DV31+$EB31
32	@IF(DW4="YES",$A*$S*0.283*12*($DY32)/2*(@TANH((2/1.25*$DY32)^3/40-0.375)*0.375+0.6+(2/1.25*$DY32)*0.01),$A*$S*0.283*12*($DY32)*(@TANH(($DY32)^3/40-0.375)*0.375+0.6+$DY32*0.01)+2*0.5*$S*$RATE)	+DW32+DZ32+EA32	+$DV32+$EB32
33	@IF(DW4="YES",$A*$S*0.283*12*($DY33)/2*(@TANH((2/1.25*$DY33)^3/40-0.375)*0.375+0.6+(2/1.25*$DY33)*0.01),$A*$S*0.283*12*($DY33)*(@TANH(($DY33)^3/40-0.375)*0.375+0.6+$DY33*0.01)+2*0.5*$S*$RATE)	+DW33+DZ33+EA33	+$DV33+$EB33
34	@IF(DW4="YES",$A*$S*0.283*12*($DY34)/2*(@TANH((2/1.25*$DY34)^3/40-0.375)*0.375+0.6+(2/1.25*$DY34)*0.01),$A*$S*0.283*12*($DY34)*(@TANH(($DY34)^3/40-0.375)*0.375+0.6+$DY34*0.01)+2*0.5*$S*$RATE)	+DW34+DZ34+EA34	+$DV34+$EB34
35	@IF(DW4="YES",$A*$S*0.283*12*($DY35)/2*(@TANH((2/1.25*$DY35)^3/40-0.375)*0.375+0.6+(2/1.25*$DY35)*0.01),$A*$S*0.283*12*($DY35)*(@TANH(($DY35)^3/40-0.375)*0.375+0.6+$DY35*0.01)+2*0.5*$S*$RATE)	+DW35+DZ35+EA35	+$DV35+$EB35
36	@IF(DW4="YES",$A*$S*0.283*12*($DY36)/2*(@TANH((2/1.25*$DY36)^3/40-0.375)*0.375+0.6+(2/1.25*$DY36)*0.01),$A*$S*0.283*12*($DY36)*(@TANH(($DY36)^3/40-0.375)*0.375+0.6+$DY36*0.01)+2*0.5*$S*$RATE)	+DW36+DZ36+EA36	+$DV36+$EB36
37	@IF(DW4="YES",$A*$S*0.283*12*($DY37)/2*(@TANH((2/1.25*$DY37)^3/40-0.375)*0.375+0.6+(2/1.25*$DY37)*0.01),$A*$S*0.283*12*($DY37)*(@TANH(($DY37)^3/40-0.375)*0.375+0.6+$DY37*0.01)+2*0.5*$S*$RATE)	+DW37+DZ37+EA37	+$DV37+$EB37
38	@IF(DW4="YES",$A*$S*0.283*12*($DY38)/2*(@TANH((2/1.25*$DY38)^3/40-0.375)*0.375+0.6+(2/1.25*$DY38)*0.01),$A*$S*0.283*12*($DY38)*(@TANH(($DY38)^3/40-0.375)*0.375+0.6+$DY38*0.01)+2*0.5*$S*$RATE)	+DW38+DZ38+EA38	+$DV38+$EB38
39	@IF(DW4="YES",$A*$S*0.283*12*($DY39)/2*(@TANH((2/1.25*$DY39)^3/40-0.375)*0.375+0.6+(2/1.25*$DY39)*0.01),$A*$S*0.283*12*($DY39)*(@TANH(($DY39)^3/40-0.375)*0.375+0.6+$DY39*0.01)+2*0.5*$S*$RATE)	+DW39+DZ39+EA39	+$DV39+$EB39
40	n/a	+DW40+DZ40+EA40	+$DV40+$EB40
41	n/a	+DW41+DZ41+EA41	+$DV41+$EB41
42	n/a	+DW42+DZ42+EA42	+$DV42+$EB42
43	n/a	+DW43+DZ43+EA43	+$DV43+$EB43
44	n/a	+DW44+DZ44+EA44	+$DV44+$EB44
45	n/a	+DW45+DZ45+EA45	+$DV45+$EB45
46	n/a	+DW46+DZ46+EA46	+$DV46+$EB46
47	n/a	+DW47+DZ47+EA47	+$DV47+$EB47
48	n/a	+DW48+DZ48+EA48	+$DV48+$EB48
49	n/a	+DW49+DZ49+EA49	+$DV49+$EB49
50	n/a	+DW50+DZ50+EA50	+$DV50+$EB50
51	n/a	+DW51+DZ51+EA51	+$DV51+$EB51
52	n/a	+DW52+DZ52+EA52	+$DV52+$EB52
53	n/a	+DW53+DZ53+EA53	+$DV53+$EB53
54	n/a	+DW54+DZ54+EA54	+$DV54+$EB54
55	n/a	+DW55+DZ55+EA55	+$DV55+$EB55
56	n/a	+DW56+DZ56+EA56	+$DV56+$EB56
57	@SUM(EA56..EA12)	@SUM(EB56..EB12)	@SUM(EC56..EC12)

A	ED	EE	EF	EG	EH	EI	EJ	EK
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54	TUBE Calculations							
55	Tube Total	Labor	Material	Total Tube	Scantling	Tube	Total Module	MAESTRO
56	Manhours	Cost	Cost	Cost	Weight (both)	Weight (both)	Weight (both)	Weight (both)
57	+AF81	+AG81	+AH81	+AI81	($AR57+$BG57+$BP57)*2/2240	+$AI81*2/2240	+EH57+EI57	132

TEXT - Plate Look-up Table

A	F	G	H	I	J	K	L	M	N
157		Cost per	Pound	- Plate					
158				1					
159			0	0					
160		1/8	+1/8	0.49	(840-4.5*$H160*25.4)*1.19405/2205				
161		3/16	+3/16	0.48	(840-4.5*$H161*25.4)*1.19405/2205				
162		1/4	+1/4	0.47	(840-4.5*$H162*25.4)*1.19405/2205				
163		5/16	+5/16	0.47	(840-4.5*$H163*25.4)*1.19405/2205				
164		3/8	+3/8	0.47	(840-4.5*$H164*25.4)*1.19405/2205				
165		7/16	+7/16	0.47	(840-4.5*$H165*25.4)*1.19405/2205				
166		1/2	+1/2	0.45	(840-4.5*$H166*25.4)*1.19405/2205				
167		9/16	+9/16	0.45	(840-4.5*$H167*25.4)*1.19405/2205				
168		5/8	+5/8	0.45	(840-4.5*$H168*25.4)*1.19405/2205				
169		11/16	+11/16	0.42	(840-4.5*$H169*25.4)*1.19405/2205				
170		3/4	+3/4	0.42	(840-4.5*$H170*25.4)*1.19405/2205				
171		13/16	13/16	0.42	(840-4.5*$H171*25.4)*1.19405/2205				
172		7/8	+7/8	0.4	(840-4.5*$H172*25.4)*1.19405/2205				
173		15/16	15/16	0.4	(840-4.5*$H173*25.4)*1.19405/2205				
174		1	1	0.39	(840-4.5*$H174*25.4)*1.19405/2205				